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Digital Innovation for Sustainability

Dissertation

zur Erlangung des akademischen Grades
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When sustainability is viewed as being a matter of survival for your business, I believe you can create massive change.

(Cameron Sinclair)

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Abstract

Sustainability is one of the most prominent topics in current debates in organizations, societies, and politics. As an umbrella term, sustainability comprises economic (e.g., fostering economic development in the Global South) (D. Schmitt & Muyoya, 2020; Zafra-Calvo et al., 2020), social (e.g., reaching gender equality) (Friedman et al., 2020) and environmental facets (e.g., tackling climate change) (Alves et al., 2020; Vargo et al., 2020). However, many grand sustainability challenges have yet to be solved as their complexity hinders the development of straightforward solutions (Lönngren & van Poeck, 2021; Sachs et al., 2023). Official agreements and regulations to drive sustainable development are developed mainly by governmental actors such as the European Union (EU) or the United Nations (UN). However, large private organizations also have significant levers for sustainability through their products and practices (Bexell & Jönsson, 2017; Kolk & van Tulder, 2010). These organizations must balance moral and legal sustainability obligations with business interests such as institutional pressure, customer perception, and market demand (Babiak & Trendafilova, 2011).

To contribute to sustainability, organizations need successful innovation to develop new, sustainable products, services, processes, or business models (Johannessen et al., 2001; Omri, 2020; Skare & Porada-Rochon, 2022). The emergence of digital technologies (e.g., cloud computing, artificial intelligence (AI)) in recent decades has fundamentally changed the nature of innovation (Yoo et al., 2012), leading to novel opportunities for achieving sustainable development. Digital innovation enables organizations to create economic, social, and environmental value (Bähr & Fliaster, 2023; Nambisan et al., 2017; Yoo et al., 2012). For example, digital innovation outcomes such as energy and carbon management systems can enhance environmental sustainability by enabling organizations to monitor, analyze, and improve environmental performance (Zampou et al., 2022).

However, the total value of digital innovation for sustainability has not yet been leveraged. To change this, a thorough understanding of the underlying dynamics of digital innovation actions (e.g., idea generation, prototype development), the digital innovation environment (e.g., competitors or customers), and digital innovation outcomes (e.g., new products or processes) is critical (Buck, Kempf, et al., 2023; Hund et al., 2021; Kohli & Melville, 2019). This dissertation aims to contribute knowledge on digital innovation for sustainability through a combination of qualitative and quantitative approaches, an integration of interdisciplinary research insights, and a set of exemplary contexts. More precisely, this dissertation sheds light on the three

categories of (1) digital innovation actions, (2) digital innovation environments, and (3) digital innovation outcomes, and analyzes their overarching implications in sustainability contexts.

First, this dissertation makes contributions to understanding the digital innovation actions required to create sustainability value. Organizations undergo a number of different activities in innovation endeavors, such as opportunity exploration and the development, implementation, and scaling of new solutions (Kohli & Melville, 2019; Oberländer et al., 2021). Digital innovations can assume two roles in relation to innovation actions: (1) they can serve *as a means* to facilitate innovation actions, or (2) they can be *the end* result of the whole process (e.g., in the form of a new mobile app or software) (Ciriello et al., 2018). This dissertation presents examples of both roles.

In terms of digital innovation as a means, this dissertation demonstrates that both online crowdsourcing and large language models are suitable decision-makers in the evaluation of innovation ideas for complex sustainability challenges. These technologies can reduce the financial and time-related bottleneck of expert jury evaluations in innovation processes. In addition, the evaluation procedure and the level of specialization of the respective challenge are two critical factors impacting evaluation performance. For digital innovation as an end, this dissertation clarifies the role of digital innovation within successful digital transformations. Rapid prototyping, building an entrepreneurial culture, ambidexterity, and the recombination of existing technologies are identified as central innovation actions to contribute to economically sustainable digital transformations.

Second, this dissertation investigates aspects of the internal (e.g., employees, culture) and the external (e.g., customers, competitors) innovation environment in digital innovation for sustainability (Kohli & Melville, 2019; Müller et al., 2019). In the internal environment, innovating digitally for sustainability requires a healthy, motivated workforce that drives the creation of sustainability value (Tarafdar et al., 2015; Zhao et al., 2020). However, working with digital technologies to create digital innovations can cause technostress, ultimately leading to health issues and reduced productivity (Ayyagari et al., 2011; Ragu-Nathan et al., 2008; Tarafdar et al., 2007). As a response, this dissertation contributes 24 technostress prevention measures as well as knowledge regarding their applicability in different types of organizations. In addition, propositions on the effectiveness of the measures for different sources of technostress are offered.

In the external innovation environment, customers are a critical factor for sustainability in terms of new products and services. Only when customers actively use an organization's digital innovation for sustainability can the sustainability value be exploited (Greenwood et al., 2021). Customer behavior and the role of digital innovations in the context of the to-go beverages and food industry are one example for the importance of pro-environmental behavior (Greenwood et al., 2021; Novoradovskaya et al., 2021). Sustainable alternatives to plastic cups exist, but their positive sustainability effect can only be realized if the alternatives are used by customers (Kauertz et al., 2019; Mitchell et al., 2014). This dissertation identifies five critical factors influencing the decision to act sustainably in the context of to-go beverages and food. In addition, this dissertation identifies different possibilities of using digital innovations to support pro-environmental behavior (e.g., in the form of information-based or process-based applications).

Third, this dissertation provides insights on the outcome category of digital innovation for sustainability. Digital innovation for sustainability can lead to novel products, services, processes, and even business models (Ciriello et al., 2018; Kohli & Melville, 2019; Nambisan, 2013). However, it is often difficult to grasp the richness of potential sustainable innovation outcomes for a new type of technology (Ciriello et al., 2018; Yoo et al., 2010). Smart urban agriculture is one exemplary context for digital innovation for sustainability. Though urban agriculture holds enormous potential for economic, social, and environmental sustainability, its implementation is often difficult (Langendahl, 2021). Digital innovation can improve the exploitation of sustainability value in this context, but it is not yet clear how outcomes might look. Against this backdrop, this dissertation develops a taxonomy of smart urban agriculture solutions to clarify the space of digital innovation outcomes in urban agriculture with relation to the role of digital technologies, data, and the selected urban agriculture approach. Additionally, 20 organizational readiness factors across cultural, strategic, or technological dimensions outline the requirements for leveraging the sustainability value of smart urban agriculture outcomes.

In advancing digital innovation for sustainability research, the last contribution is the presentation of a research agenda for digital social innovation, a sub-theme of digital innovation for sustainability. The derived research pathways span topics such as (1) the role of digital social innovation ecosystems, (2) the role of digital social innovations for potential conflicts and synergies between sustainability dimensions, (3) the integration of digital social innovations into different contexts and environments, (4) the role of data, and (5) the assessment

of digital social innovation success. This research agenda combines insights across digital innovation actions, environments, and outcomes. The resulting contribution pinpoints the direction of future research in this area.

In summary, this dissertation makes contributions to understanding digital innovation actions, environments, and outcomes in digital innovation for sustainability. The overarching research paradigm is that of behavioral science, with both qualitative and quantitative research methodologies included throughout the chapters. The results of this dissertation can help researchers and practitioners alike to understand and leverage digital innovation to create sustainability value.

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List of Abbreviations

AI.....*Artificial Intelligence*
AIS .....*Association for Information Systems*
DSI ..... *Digital Social Innovation*
DT.....*Digital Transformation*
ICT .....*Information and Communication Technology*
IoT ..... *Internet of Things*
IS ..... *Information Systems*
IT ..... *Information Technology*
LLM ..... *Large Language Model*
NPV.....*Negative Predictive Value*
PPV.....*Positive Predictive Value*
RPs .....*Research Pathways*
SDGs .....*Sustainable Development Goals*
SUA.....*Smart Urban Agriculture*
TBL .....*Triple Bottom Line*
TGRS..... *To-go Reusable Systems*
TPB.....*Theory of Planned Behavior*
UN .....*United Nations*

1 Introduction

1.1 Motivation

Our world faces a multitude of complex challenges. One of the most prominent examples is climate change, which is at the top of almost every political and organizational agenda (Alves et al., 2020). Climate change involves increasing levels of atmospheric carbon dioxide and other greenhouse gases, drastically rising surface temperature, extreme heat events, significant glacier mass loss, loss of biodiversity, water scarcity, and high wildfire risk (Y. Li et al., 2023; Vargo et al., 2020). These environmental results of climate change incur direct social and economic consequences. For example, past heat waves have caused tens of thousands of deaths (Auffhammer, 2022), and the damages of climate change (e.g., crop shortfalls) are estimated to cost Germany alone around 900 billion euros by 2050 (Flaute & Reuschel, 2022).

Climate change, however, is not the only unsolved sustainability challenge with significant consequences for individuals, industries, and societies. Sustainability goes beyond environmental concerns and is "the principle of ensuring that our actions today do not limit the range of economic, social, and environmental options open to future generations" (Elkington, 1997, p. 20). Sustainability therefore targets integrating economic, social, and environmental goals. On the social side, the COVID-19 pandemic has had a massive impact on recent years. Not only did the pandemic take an estimated seven million human lives by November 2023 (World Health Organization, 2023), but it has also demonstrated the fragility of the global healthcare system, inequalities in access to healthcare, and the high interdependencies of international trade systems (Angeler et al., 2022; Hernández-Vásquez et al., 2021; Mahendradhata et al., 2021).

While the two examples of climate change and COVID-19 concern entirely different topics, they are both related to the overall goal of sustainability and sustainable development (Graf-Drasch et al., 2022). In line with the definition of sustainability, sustainable development describes "development that meets the needs of present generations without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). The achievement of sustainable development is often assessed via the United Nations' (UN) 17 Sustainable Development Goals (SDGs) (United Nations, 2015). However, despite significant advances in sustainability research across disciplines (e.g., Bähr & Fliaster, 2023; Gholami et al., 2016; Langemeyer et al., 2021), many sustainability challenges have not been solved.

Official agreements regarding sustainable development are primarily reached by governmental actors, such as the UN, international climate conferences, or the European Union (e.g., United Nations, 2015). However, the responsibility to drive sustainable development also extends to businesses and society (Bexell & Jönsson, 2017). Large international organizations in particular have significant levers for sustainable development, such as creating sustainable products or applying sustainable business practices (Kolk & van Tulder, 2010). However, businesses' quest for sustainability can also create tensions when sustainable practices come at the price of lower profit margins (Babiak & Trendafilova, 2011). As a result, businesses' motives to drive sustainable development include not only moral or legal reasons but must be balanced with business considerations. Businesses participate in sustainable actions to adhere to institutional pressure, improve their image towards customers and other network partners, or even fulfill market demands (Babiak & Trendafilova, 2011).

Innovation is critical for businesses to drive sustainable development (Omri, 2020; Skare & Porada-Rochon, 2022). Innovation is centered around newness and includes "any idea, practice, or material artifact perceived to be new by the relevant unit of adoption" (Zaltman et al., 1973, p. 10). Generally, innovations can address products and services, processes, and business models (Johannessen et al., 2001). Innovation can lead to improved processes that require fewer resources, are healthier for employees, or can be executed in less time, thereby contributing to sustainable development (Gerstlberger et al., 2014). From a product perspective, innovation can also create products that either foster sustainable behavior (e.g., smart home solutions) or are sustainable in terms of material input and usage (e.g., electric vehicles) (Noori et al., 2020; Rommetveit et al., 2024; Silvestre & Ţîrcă, 2019).

Sustainability challenges inhibit strong interdependencies on a global level (Hallding & Blixt, 2020). For example, improving access to healthcare through mobile applications can drive sustainability for some parts of society (SDG 3, Good Health and Wellbeing) while disadvantaging those without smartphones (SDG 10, Reduced Inequalities). To capture and account for these interdependencies, innovation for sustainability must incorporate diverse perspectives from a wide range of stakeholders (e.g., businesses, customers, and policymakers) throughout the innovation process (Head, 2008; Jenkins-Smith et al., 2020; McKane et al., 2017). However, involving stakeholders can be a timely and costly process, requiring businesses to adequately coordinate innovation activities with stakeholders (Loureiro et al., 2020). Fortunately, with the ongoing digitalization, new digital technologies have emerged that can be used independently of time and location to enable broad stakeholder involvement (Di

Gangi et al., 2010; Leimeister, 2010; Loureiro et al., 2020; Nambisan, 2013). For example, online platforms can serve as easily accessible tools for co-developing novel ideas with various stakeholders. Similarly, straightforward communication tools such as videoconferencing can bridge the spatial gap between innovation partners (Bonina, Koskinen, et al., 2021; Oborn et al., 2021; Ravishankar, 2021; Richardson-Ngwenya et al., 2019).

Digital technologies not only facilitate communication during traditional innovation but also "radically change the nature of […] innovations" (Yoo et al., 2012, p. 1398). Integrating digital technologies to create and scale new, value-adding business processes, services, products, or business models is conceptualized as digital innovation (Hund et al., 2021). Digital innovation differs from traditional innovation because digital technologies create substantial convergence and generativity (Ciriello et al., 2018). Convergence describes the phenomenon whereby digital innovation integrates components (e.g., product features) previously spread across different innovations. Generativity refers to the dynamic and adaptable nature of digital innovations, which allows for, for example, the adaptation and change of digital products even after their release. An example of generativity is integrating new functionality into an existing mobile application through an update – a process that is not possible in the case of a non-digital product such as a book or screwdriver (Ciriello et al., 2018).

Digital innovation is a core activity in every digital transformation and has been heavily researched in business contexts (Kaganer et al., 2023; Nambisan et al., 2017; Soluk & Kammerlander, 2021). For example, acquiring digital companies has been found to drive the creation of digital knowledge bases for the acquirer, yielding more effective digital innovation capabilities as a result (Hanelt, Firk, et al., 2021). However, the tremendous potential of digital innovation to create value is not limited to economic aspects such as profit margins or market shares. Digital innovation also has the potential to drive sustainable development across the pillars of economic, social, and environmental sustainability (Bähr & Fliaster, 2023; Corbett et al., 2022; George et al., 2021).

The following three brief examples illustrate digital innovation for sustainability research in an economic, social, and environmental context. First, in terms of economic sustainability, digital innovation in products, services, and processes can substantially drive economic development in bottom-of-the-pyramid communities (i.e., people who earn less than USD 2 per day) (Tarafdar et al., 2013). At the bottom of the pyramid, a disconnectedness between producers and customers often hinders development. However, digital innovations can bridge the spatial,

temporal, financial, and informational distances in markets due to the characteristics of the involved digital technologies (Tarafdar et al., 2013).

Second, energy and carbon management systems are examples of digital innovations that positively impact environmental sustainability (Zampou et al., 2022). These systems enable organizations to monitor and analyze data about environmental performance indicators (e.g., fuel consumption, carbon emissions) throughout their supply chain, enabling conscious decision-making on projects to improve environmental performance (Zampou et al., 2022).

Lastly, social sustainability is less intuitive than the economic and environmental pillars regarding the topics it comprises. It comprises various issues, such as education, gender equality, and health and wellbeing (Kneissel et al., 2023). In healthcare, digital innovation creates enormous potential (Keijzer-Broers & de Reuver, 2016; Meister et al., 2019). For example, during the COVID-19 pandemic, digital innovations in the form of telemedicine reduced hospital overcrowding, providing faster access to healthcare and creating a safer environment for medical personnel (Oborn et al., 2021).

These three examples demonstrate the value of digital innovations for driving sustainable development. However, given that the progress towards the achievement of almost all 17 SDGs is significantly off the communicated time plan, the full potential of digital innovation for sustainability has yet to be leveraged (Sachs et al., 2023). Many barriers exist to exploiting the full value of digital innovation for sustainability. Challenges range from the strategic and cultural internal challenges of innovating organizations to resource constraints, regulatory issues, and low customer adoption rates (Buck, Kempf, et al., 2023). In addition, the potential of technology-based innovation is highly dependent on the current economic development level of the respective community, hinting at possible interdependencies between the SDGs (Omri, 2020).

In summary, the criticality of addressing sustainable development is unprecedentedly high. In this context, digital innovation for sustainability is one promising solution avenue as “some of the most exciting research ideas and entrepreneurial ventures are due to the convergence of the digital and sustainability imperatives” (George et al., 2021, p. 1020). However, to fully exploit the value of digital innovation for sustainability, a better conceptualization of digital innovation within a sustainability context is needed to address current barriers.

1.2 The Role of Digital Innovation for Sustainability in Information Systems

Digital innovation for sustainability combines research on innovation, digital technologies, and sustainability sciences (George et al., 2021). Consequently, how this research area fits into the topics discussed within the Information Systems (IS) community is not trivial. IS research traditionally attends to a wide range of interdisciplinary topics at the intersection of information technology (IT) and organizations (Peffers et al., 2007). To name just a few topics, research has considered cybersecurity, social media, digital innovation, and digital transformations (Dittes & Smolnik, 2019; Y. Han et al., 2020; Jalali et al., 2019; Maier et al., 2021; Nambisan et al., 2017; Vial, 2019). On a methodological level, selected approaches vary regarding their focus on qualitative versus quantitative and behavioral versus design-oriented research paradigms, spanning approaches such as interview studies, action research, mathematical models, and design science research (Palvia et al., 2003; Wilde & Hess, 2007). Given the sheer variance in topics and approaches, finding common ground for defining the core research topics of IS (research) is not trivial.

However, a few boundary conditions govern research in the IS field. Most fundamentally, IS research takes a socio-technical perspective on the phenomena under investigation (Alter, 2008; L. H. Fischer & Baskerville, 2023; Lyytinen & Newman, 2008; Mumford, 2006; Sarker et al., 2019). Put differently, "IS are, however, more than their hardware, software, and data. IS also encompass the people and the work practices needed to produce the information the system yields. They are, therefore, characterized not as technical but as sociotechnical" (Briggs et al., 2010, p. 14). Existing, well-established definitions of IS incorporate the field's socio-technical nature and define IS, for example, as "an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals" (Watson et al., 2010, p. 24) or as the integration of a technical, informational, and social artifact (A. S. Lee et al., 2015). As such, IS research does not prioritize either the technical or the social perspective and instead seeks to balance both to reach economic and social goals (L. H. Fischer & Baskerville, 2023; Mumford, 2006; Sarker et al., 2019).

Given the agreed-upon characteristics of IS research, the question of how digital innovation for sustainability fits the field emerges. Hund et al. (2021) analyzed the components of the digital innovation phenomenon, as illustrated in what they name a "three-layer conceptualization" (Figure 1). It comprises the digital object, the digital technology, and digital innovation.

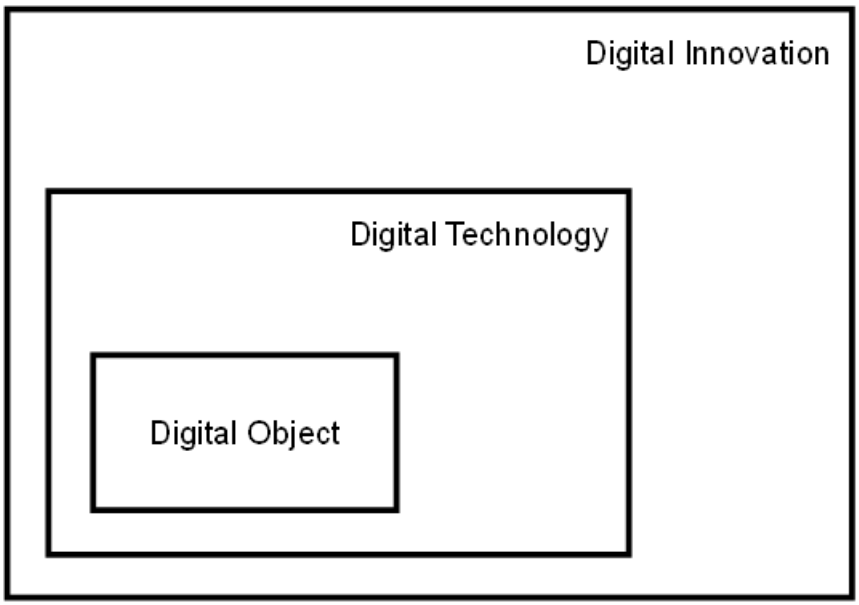


Figure 1: Conceptualization of Digital Innovation based on Hund et al. (2021)

The digital object describes the technical foundation of any digital innovation and comprises both purely nonmaterial and hybrid objects containing at least one bitstring (Hund et al., 2021). Examples of digital objects include computer systems, datasets, or peripherals (Runde & Faulkner, 2019). The digital object is solely on the technical side of research. For digital innovation to fit into the socio-technical understanding of IS research, the digital technology layer thus needs to incorporate the social perspective (Hund et al., 2021).

Digital technology is a term widely used in IS research but rarely explicitly defined (Runde & Faulkner, 2019). If one hands a digital object to a group of 100 people, chances are high that usage of the respective object differs substantially across the group. These so-called fluid boundaries of digital objects – that is, the inability to know how exactly a digital object will be used – are a core assumption of digital innovation theories (Yoo et al., 2010). Accordingly, the same digital object can have entirely different roles, depending on the context it is used in and the opportunities different social actors associate with it (Hund et al., 2021; Runde & Faulkner, 2019; Yoo et al., 2010). The digital object becomes a digital technology only when social actors have clarified its application purpose (i.e., meaning) (Hund et al., 2021). Digital technologies themselves are therefore socio-technical at their core: they combine a technical perspective on digital objects with the social surroundings (e.g., people, work practices, etc.) in which they are embedded (Runde & Faulkner, 2019).

Lastly, digital innovation comprises both digital objects and digital technologies. Synthesizing existing definitions, Hund et al. (2021, p. 6) define digital innovation as “the creation or

adoption, and exploitation of an inherently unbounded, value-adding novelty (e.g., product, service, process, or business model) through the incorporation of digital technology." During the digital innovation process, reciprocal dynamics emerge between the social and technical components. On the technical side, digital technologies provide various technological capabilities to support and enable innovation, impacting the social actors responsible for the innovation process. At the same time, the social actors' relationships with each other and towards digital technologies affect how the technology is used (Avital & Te'eni, 2009; Msiska & Nielsen, 2018). Only when digital innovation's technical and social perspectives are aligned and balanced can a digital innovation endeavor succeed and economic and humanistic goals be reached (Msiska & Nielsen, 2018). Consequently, digital innovation fits directly into IS research's core nature of analyzing socio-technical phenomena (Avital & Te'eni, 2009; Hund et al., 2021; Msiska & Nielsen, 2018; Nambisan et al., 2017; Runde & Faulkner, 2019).

Not all digital innovations focus on a sustainability context, where the *value-adding novelty* refers not only to financial profits but also to social and environmental goals. The IS community has long addressed the potential and responsibility of IS research to contribute to sustainable development (Gholami et al., 2016; Malhotra et al., 2013; Suseno & Abbott, 2021; Watson et al., 2010). In summarizing this sustainability orientation, Sarker et al. (2019) explicitly refers to how the social and technical perspectives jointly create value for both instrumental outcomes (i.e., the economic perspective, for example, efficiency and productivity) and so-called humanistic outcomes (i.e., the social and environmental perspective, for example, wellbeing and equality). Therefore, not only digital innovation but also digital innovation for sustainability directly speaks to the core of IS research.

Digital innovation for sustainability research within the IS domain can be structured into three categories: (1) innovation actions, (2) innovation environment, and (3) innovation outcome (Figure 2) (Kohli & Melville, 2019).

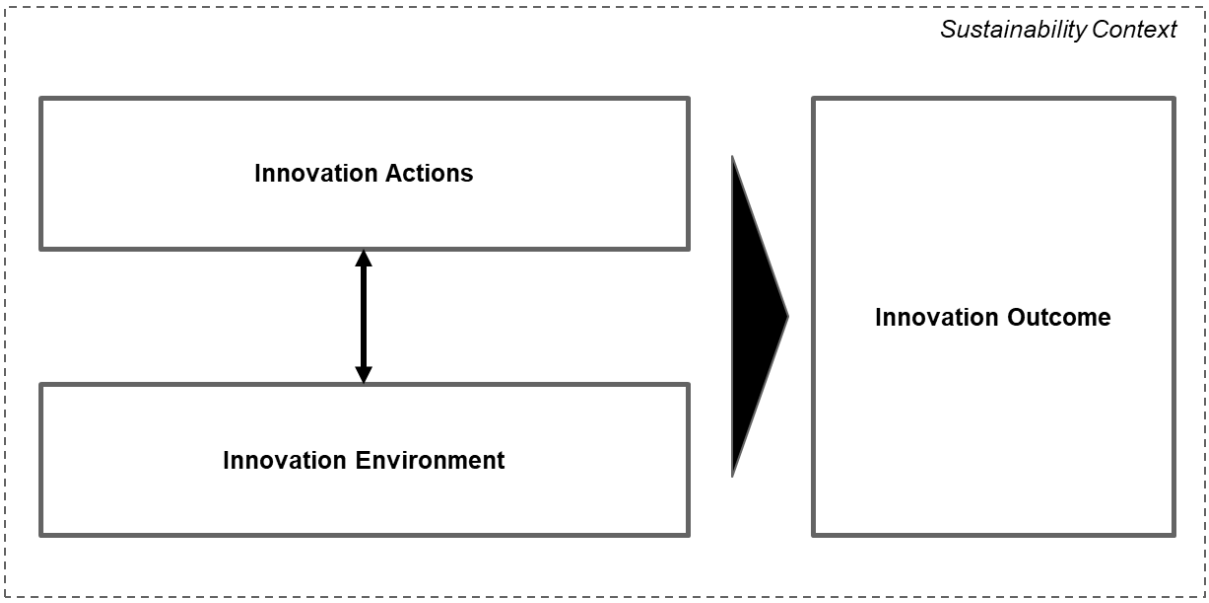


Figure 2: Digital Innovation for Sustainability Framework

First, innovation actions include the creation, adoption, and exploitation of novel ideas during innovation itself (Hund et al., 2021). Research has identified various other innovation actions conducted during innovation endeavors, such as detecting ideas, prototyping, and maintenance (Auf der Mauer et al., 2019; Kohli & Melville, 2019; Röglinger et al., 2020). An extensive literature review synthesizes the different actions into a framework of four key innovation actions: initiation, development, implementation, and exploitation (Kohli & Melville, 2019). Initiation relates to all activities and topics on opportunity detection in the digital innovation domain. Development comprises the design of digital innovations (e.g., through design science research) and issues related to their adoption. Implementation covers all topics related to installing and maintaining digital innovations, and lastly exploitation considers how to achieve maximum value from existing digital innovation (Kohli & Melville, 2019). The first category of digital innovation for sustainability research thus centers on the specific innovation actions needed to create sustainable outcomes (Butler & Hackney, 2015; Hosseini et al., 2018; Sandeep & Ravishankar, 2015).

Second, digital innovation strongly depends on the context in which it is embedded (Hund et al., 2021; Runde & Faulkner, 2019). The innovation environment is therefore a second fundamental perspective in digital innovation for sustainability research. “Environment” as a category does not refer to the natural environment as part of the three pillars of sustainability but rather considers the inter- and intra-organizational context digital innovation occurs in. The innovation environment comprises the internal (organizational) environment (e.g., learning,

culture, strategies) and the external (competitive) environment (e.g., customers, competitors, market dynamics, politics) (Kohli & Melville, 2019). Both environment types have a reciprocal relationship with the innovation actions. For example, research in this category analyzes factors in the internal and external environment that promote or hinder the development of sustainable digital innovations (Arena et al., 2018; Munthali et al., 2018; Vahtera, 2008).

Third, Hund et al.'s (2021) definition refers to value-adding novelties, which describe the outcome of digital innovation for sustainability. Innovation outcomes denote the result of the innovation actions and center on what has been initiated, developed, implemented, and exploited. On the customer side, digital innovation for sustainability can lead to new products or services (Nambisan et al., 2017). Additional outcomes could include modified business processes (Ciriello et al., 2018). Given the magnitude of change initiated by digital technologies, outcomes may even comprise entirely new sustainable business models (Ciriello et al., 2018; Kohli & Melville, 2019). Research in this third category focuses on the sustainability value of digital innovations, different outcome types, and value creation mechanisms (Bonina, López-Berzosa, & Scarlata, 2021; Hanelt et al., 2017; Moss et al., 2020).

To summarize, digital innovation for sustainability research can be analyzed through the lens of the three categories of innovation actions, innovation environment, and innovation outcomes.

1.3 Aim and Outline of this Dissertation

Given the tremendous sustainability challenges dominating global political, organizational, and societal agendas, action is needed. As Gholami et al. (2016, p. 521) assert, “the IS scholarly community needs to help create a sustainable society. While there is an emerging body of IS scholarship under the banner of green IS, we strongly believe that we need to step up these efforts.” Indeed, digital innovation has proven to be a suitable tool for businesses to address sustainability challenges, but its full potential has yet to be harvested (Bähr & Fliaster, 2023; George et al., 2021). A sound scientific understanding of the underlying dynamics is crucial for practitioners to successfully initiate, develop, implement, and exploit digital innovations in sustainability contexts (Kohli & Melville, 2019). Thus, this dissertation aims to provide scientific insights that support sustainability value creation through digital innovation. Using the theoretical lens of socio-technical information systems (Mumford, 2006), this work aims to extend the theoretical and practical knowledge base on using digital innovation for sustainability by assessing different contexts through qualitative and quantitative research

methodologies. The research aim is fourfold, comprising (1) the innovation actions, (2) the innovation environment, (3) the innovation outcomes, and (4) an overarching synthesis of all three categories. Examples of digital innovations creating economic, social, and environmental value elucidate the underlying processes and interactions between the social and technical components. For both theory and practice, this dissertation offers a step towards reducing the barriers to leveraging digital innovation for sustainability. The following paragraphs outline the four research areas' aims and research activities.

Research Focus 1: Innovation Actions

In the context of actions executed during digital innovation for sustainability, digital technologies can adopt two distinct roles: (1) they may be employed throughout the innovation process itself to enable collaboration, thereby functioning *as a means*; or (2) they might constitute a component of the resulting innovation outcomes, thereby serving *as an end* (Ciriello et al., 2018; Nambisan et al., 2017). When considered as a means, digital technologies play a supportive role in creating novel sustainable solutions. Examples include digital platforms that facilitate collaborative innovation among individuals or big data analysis to extract solution ideas (Bonina, Koskinen, et al., 2021; Kelly & Noonan, 2017). Consequently, the outcome of the innovation process can manifest as either digital or non-digital (Ciriello et al., 2018; Nambisan et al., 2017). That said, when viewed as an end, digital technologies are an integral part of the digital (or hybrid) innovation outcome, examples being the development of a new mobile application for tracking water consumption or a smartwatch supporting healthy lifestyles (Ciriello et al., 2018; Yoo et al., 2010).

In Subchapter 3.1, this dissertation illustrates the potential of digital innovation for sustainability when utilizing digital technologies as a means during innovation actions. To this end, the potential of crowdsourcing and generative artificial intelligence (AI) for idea evaluation in the complex problem domain are considered. Many of the challenges associated with reaching sustainable development are complex and unique, and there is no blueprint for how to solve them. When implementing solution ideas, it often takes months, sometimes even years and decades, to reveal their effects (Rittel & Webber, 1973b). Despite the lack of a clear solution, it is broadly agreed that various stakeholders must be involved in developing solutions (Head, 2008; Jenkins-Smith et al., 2020; McKane et al., 2017). To span geographic distance and ease collaboration for innovation, innovation contests on sustainability issues hosted by digital platforms are promising for both profit and non-profit-oriented organizations.

However, due to the easy access they offer collaborators, these contests often create the challenge of an overabundance of innovation ideas, all of which need to be evaluated (Blohm et al., 2013; Chesbrough, 2006; Gimpel, Graf-Drasch, et al., 2020). Outsourcing idea evaluation from expert juries to either digital crowdsourcing platforms (Görzen & Kundisch, 2016; M. Klein & Garcia, 2015; P. R. Magnusson et al., 2016) or a large language model (LLM) (Gao et al., 2023; Kocoń et al., 2023) may reduce the existing bottleneck in idea evaluation. This dissertation compares the evaluation results of crowdsourcing and LLMs to those of expert juries in the context of sustainability problems as little is known about their suitability as idea evaluators. The results highlight the potential of both evaluators for improving innovation actions, shed light on the role of specialization for evaluation quality, and indicate specific evaluation procedures that improve performance.

Subchapter 3.2 extends prior findings on digital technologies as an end during innovation actions. Many organizations have sophisticated plans for developing digital innovations for sustainability with digital technologies as an end (Oberländer et al., 2021). However, digital innovation is not an isolated organizational activity but is embedded within the organization-wide digital transformation (DT) strategy (Kaganer et al., 2023; Oberländer et al., 2021). Existing studies have portrayed digital innovation as one critical component of DT to rebalance organizational structures, identities, and business models in light of digitalization (Drechsler et al., 2020; Kaganer et al., 2023; Oberländer et al., 2021; Vial, 2019). Understanding the digital innovation actions fostering such transformations is essential given that a successful DT is critical for organizations' economic sustainability (A. Singh & Hess, 2017). This dissertation derives 23 change patterns affecting both the social and technical sides of organizations within DTs. The assessment pinpoints rapid prototyping, an entrepreneurial culture, ambidexterity, and the recombination of existing technologies as essential features of digital innovation within the overall DT. Further, organizational DTs are shown to be a multi-level phenomenon spanning, for example, individuals, departments, organizations, and entire ecosystems. The results show that change unfolds in continuous, episodic, or hybrid ways.

Research Focus 2: Innovation Environment

The second research focus of this dissertation lies in analyzing the dynamics of the internal and external innovation environment when innovating digitally for sustainability (Kohli & Melville, 2019).

The socio-technical nature of digital innovation for sustainability implies that organizations can only succeed in their innovation endeavors if, next to leveraging promising new technologies, they also pay sufficient attention to the social component (Hund et al., 2021; Mumford, 2006; Runde & Faulkner, 2019; Sarker et al., 2019). The internal innovation environment focuses on many aspects of the social component and includes, for example, working culture, roles and responsibilities, work routines, and topics around knowledge management (Ciriello et al., 2018; Kohli & Melville, 2019; Kolotouchkina et al., 2022; Jessica Lee et al., 2014). Organizations and their managers are responsible for creating internal environments that benefit innovation (Kohli & Melville, 2019). Hence, it is essential to understand how the internal environment can either hinder or promote digital innovation for sustainability.

While the main focus of digital innovation for sustainability research addresses its positive benefits, such innovation also poses certain risks for the internal environment. The use of digital technologies (e.g., during digital innovation actions) can also impact health (Ragu-Nathan et al., 2008). The stress caused by using digital technologies – termed "technostress" – is one prominent risk (Ragu-Nathan et al., 2008; Tarafdar et al., 2019). Aspects such as information overload or complexity caused by digital technologies (Ragu-Nathan et al., 2008; Tarafdar et al., 2015; Tarafdar et al., 2007) can induce stress reactions in employees, potentially leading to severe psychological and physiological consequences such as burnout, depression, or a higher likelihood of heart problems (Maier, Laumer, & Eckhardt, 2015; Ragu-Nathan et al., 2008; Srivastava et al., 2015). In addition to the moral and legal responsibility of organizations to protect employees' health, technostress can also hinder digital innovation for sustainability by causing an increase in employee sick days, a reduction in productivity, or resistance to innovating with digital technologies (Tarafdar et al., 2015; Tarafdar et al., 2007; Zhao et al., 2020). Thus, when employees in the internal environment suffer from technostress, their health status is both unsustainable and also negatively impacts the success of innovation actions aimed at sustainability (Chandra et al., 2019). Consequently, it is vital to understand how to prevent technostress from occurring in the first place (Salo et al., 2017).

Research has provided many successful applications of technostress prevention measures that allow employees to stay healthy (thereby fulfilling one aspect of social sustainability) and continue conducting their work (e.g., innovation activities) (Salo et al., 2020; Salo et al., 2017; Tarafdar et al., 2015; Tu et al., 2008). However, a comprehensive overview of what can and needs to be done is missing. To address this gap, Subchapter 4.1 in this dissertation synthesizes 24 technostress prevention measures by combining a structured literature review, a Delphi

study, and focus groups. The results shed light on differences in primary, secondary, and tertiary prevention and offer propositions on how prevention measures vary in their effectiveness for targeting different sources of technostress.

While organizations themselves can directly influence the internal innovation environment, the external (competitive) environment cannot be changed easily. Nevertheless, the structure of the competitive landscape, policies and regulations, and customer groups strongly impact the success of innovation initiatives and thus the possible value in terms of sustainability improvements (Kohli & Melville, 2019; Misuraca & Pasi, 2019). In the case of customers, their perception of digital innovations for sustainability is critical. Even if an organization develops a promising new solution with significant sustainability potential, the materialized impact will be zero if end users (e.g., employees using the process or customers using a product/service) are not willing to adopt and use the solution (Greenwood et al., 2021).

This becomes especially clear in the case of waste generated by the packaging of to-go beverages and food, with an estimated 1.2 billion disposable coffee cups ending up in waste per year in Germany alone (Kauertz et al., 2019; Mitchell et al., 2014). Though a simple, sustainable innovation is available as an alternative – namely reusable systems – their adoption rate has barely changed in the past decade as customers' routine consumption behaviors are challenging to change (Ertz et al., 2017; Novoradovskaya et al., 2021; Umweltbundesamt, 2021). For organizations creating sustainable innovations, this raises the question of how they can improve the adoption of their products and services to scale their business. In several other domains (e.g., e-commerce, mobility), research has provided evidence that leveraging digital innovation can foster the adoption of sustainable solutions (M. Berger et al., 2022; Gimpel et al., 2022; Zimmermann et al., 2024). For example, visually nudging customers towards sustainable products in an online supermarket is a digital innovation that can significantly drive pro-environmental behavior (M. Berger et al., 2020). Subchapter 4.2 of this dissertation dives into the example of waste in the to-go beverages and food sector and conducts a market analysis on applications of digital innovation as it is currently unknown how organizations in the reusable system industry leverage digital innovation to drive usage rates. The resulting 15 applications affect different impact factors of sustainable behaviors (e.g., environmental norms, perceived behavioral control, or subjective norms) and shed light on potential levers for digital innovation to increase the stagnating usage rates of sustainable reusable systems in the to-go beverages and food sector.

Research Focus 3: Innovation Outcomes

The third research focus in this dissertation presents the outcome category. Outcomes of digital innovation for sustainability comprise products, services, processes, and even business models (Ciriello et al., 2018; Kohli & Melville, 2019; Nambisan, 2013). When digital innovation and new technologies create a new field of business through their generative power, it is often difficult to grasp the richness of potential sustainable outcomes (Ciriello et al., 2018; Yoo et al., 2010). For example, the current massive media attention on generative AI has sparked several studies on potential new digital products and services and their sustainability impact (Barros et al., 2023; Jovanovic & Campbell, 2022; R. Schmidt et al., 2023; Thirunavukarasu et al., 2023). Similarly, digital innovation in agriculture has led to entirely new business models and has opened up the possibility of shifting parts of it from rural areas into cities for what has been called "urban agriculture" (M. Carolan, 2020; Goodman & Minner, 2019; Langemeyer et al., 2021). Urban agriculture could yield an annual 15 billion kilowatt-hours of energy savings and 180 million tons of additional food, representing substantial positive potential for economic, social, and environmental sustainability (Clinton et al., 2018).

However, city characteristics such as heat stress or sealed surfaces and the resulting challenging environmental conditions hinder exploitation of the full potential value for sustainable development (Gimpel, Graf-Drasch, et al., 2021; Lüttge & Buckeridge, 2020). Applying digital innovation in urban agriculture (i.e., smart urban agriculture (SUA)) can address these challenges by optimizing food production in terms of efficiency, quality, and sustainability (Balafoutis et al., 2017; De Bon et al., 2010). Examples of such applications include highly automated greenhouses in cities or sensor-based watering systems (Hugo et al., 2021; Shamshiri et al., 2018). Given the novelty of SUA, many of the respective projects do not survive economically due to substantial initial investment costs, lacking the right (technical) capabilities within the workforce, presenting an unsuitable selection of digital technologies in the development phase, or suffering from the inability to scale and exploit the solutions permanently (Langendahl 2021).

As a response, this Chapter 5 develops a research- and industry-backed taxonomy of SUA solutions to better structure the space of digital innovation outcomes in the SUA realm. Additionally, 20 organizational readiness factors describe how to better leverage the sustainability value of SUA outcomes. The results allow a conceptualization of digital

innovation outcomes in urban agriculture, which is needed to drive their adoption and thus sustainable development in cities.

Research Focus 4: Synthesis

As a fourth and last research focus, this dissertation aims to synthesize the existing knowledge in the three categories of innovation actions, environments, and outcomes. Such a synthesis forms the basis for deriving a structured overview of future research needs. Existing research has yielded valuable insights in the three categories, but two factors hinder an integrated assessment of digital innovation for sustainability knowledge that goes beyond individual use cases. First, given its high interdisciplinarity (Tarafdar & Davison, 2018), research is scattered across academic disciplines ranging from computer science to behavioral science, environmental science, and economics. Second, various terms are used to address research in the area of digital innovation for sustainability. Examples include digital eco-innovation, Green IT and Green IS, and IT-enabled social innovation (Butler & Hackney, 2015; Carberry et al., 2019; Gogan et al., 2020). All of these fall under digital innovation for sustainability, but they partially address different subdomains. Within this conglomeration of terms, one has emerged as particularly comprehensive, spanning all three sustainability dimensions, all three categories, and various applications of digital technologies at the same time: digital social innovation (DSI) (Bonina, López-Berzosa, & Scarlata, 2021; Gebken et al., 2021; Qureshi et al., 2021; Suseno & Abbott, 2021).

DSIs are defined as “digital solutions to social challenges” (Bria, 2015, p. 4). The term DSI is relatively new within the IS community, and the most fundamental studies have all been published only since 2017 (e.g., Bonina, López-Berzosa, & Scarlata, 2021; Buck, Krombacher, et al., 2023; e.g., Gebken et al., 2021; Mehmood & Imran, 2021; Qureshi et al., 2021). To effectively drive DSI research, it is critical for the IS community to understand (1) different dimensions of DSI, (2) existing knowledge, and (3) critical research pathways (RPs). Only then can we create common ground for conceptualizations of DSI, which guides future endeavors to leverage digital innovations' potential for sustainability. Therefore, Chapter 6 presents a structured literature review on DSI and the surrounding terms to derive six research clusters and 12 research pathways. The results suggest the role of DSI ecosystems, the role of DSIs for potential conflicts and synergies between sustainability dimensions, the integration of DSI into different contexts and environments, the role of data, and the assessment of DSI success as central topics for DSI research.

Summarizing the aims of the four research focus areas presented above, this dissertation strives to shed light on the importance of digital innovation for sustainability by investigating innovation actions, environment, and outcomes. This dissertation contributes to the IS community's understanding of digital innovation for sustainability from a socio-technical perspective by providing theoretical and practical implications across the three categories and developing a research agenda for DSI.

In Chapter 2, the theoretical foundations of both digital innovation more generally and digital innovation for sustainability in particular are presented, followed by an overview of the methodological backbone that builds the basis for the studies presented in later chapters. Chapter 3 assesses the innovation actions in two examples of digital innovation for sustainability – one focusing on digital technologies as a means during idea evaluation for complex problems and the other assessing the role of digital technologies as an end in DTs. Chapter 4 examines the innovation environment by studying technostress prevention in the internal environment and possibilities to impact customer adoption rates within the reusable systems sector in the external environment. Chapter 5 focuses on the third category, namely innovation outcomes, and develops a taxonomy of smart urban agriculture solutions. Chapter 6 synthesizes knowledge across the three categories from various academic domains and develops a research agenda for digital social innovation. Finally, Chapter 7 discusses the dissertation's theoretical and practical implications, outlines future research opportunities and limitations, and concludes this academic work. Figure 3 presents the structure of this dissertation.

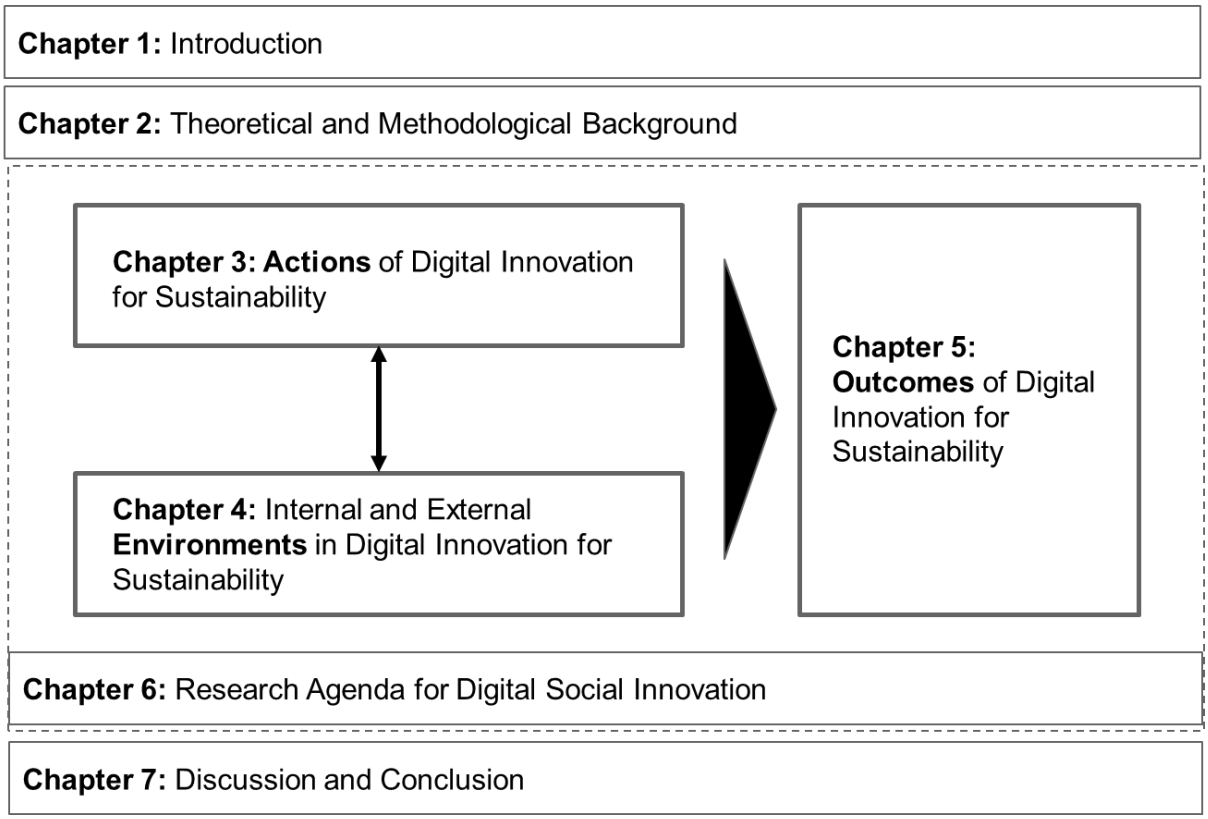


Figure 3: Structure of this Dissertation

During the process of developing this dissertation, parts of Chapters 3 through 6 were published in conference proceedings and peer-reviewed journals as part of a regular scholarly discourse or are under consideration for joint publications with coauthors[1]. Major parts of Chapter 3 conform with Gimpel, Laubacher, et al. (forthcoming) and Gimpel, Oberländer, et al. (forthcoming). Major parts of Chapter 4 conform with M. Berger et al. (2023)[2] and Schäfer (forthcoming). Major parts of Chapter 5 conform with Christmann et al. (2022)[3] and Christmann et al. (2024)[4]. Lastly, major parts of Chapter 6 conform with Graf-Drasch et al. (2022)[5] and Lindenthal et al. (forthcoming).

[1] This doctoral thesis follows the "Promotionsordnung der Mathematisch-Naturwissenschaftlich-Technischen Fakultät der Universität Augsburg (in der Fassung vom 22.7.2015)" and the "Handreichung des Instituts für Materials Resource Management (MRM) für Doktorandinnen und Doktoranden zur Einbindung von Vorveröffentlichungen in eine monografische Dissertation im Rahmen einer Promotion zum Dr.-Ing. an der Mathematisch-Naturwissenschaftlich-Technischen Fakultät (MNTF) der Universität Augsburg (in der Fassung vom 09.01.2020)".

[2] https://link.springer.com/article/10.1007/s11573-023-01159-3

[3] https://aisel.aisnet.org/wi2022/digital_cities/digital_cities/11/

[4] https://link.springer.com/article/10.1007/s12599-024-00863-w

[5] https://aisel.aisnet.org/ecis2022_rp/39/

2 Theoretical and Methodological Background

2.1 Digital Innovation

Digital innovation is a heavily researched field in the IS community. A topic search on digital innovation in the 11 most prestigious IS journals (i.e., the Senior Scholars' List of Premier Journals; Association for Information Systems, 2023) yields 115 results. The earliest study within that sample of journals from 2010 takes a product-centric, architectural perspective on digital innovation and derives a research agenda for the field (Yoo et al., 2010). In the subsequent years, IS research has built on and extended insights, complementing the idea of digital innovation for products with digital innovation for services (Lusch & Nambisan, 2015), processes (Fichman et al., 2014), and business models (Ciriello et al., 2018; Hund et al., 2021). As with most research phenomena, digital innovation has no universal definition. Instead, several studies have provided definitions with varying nuances in how digital innovation is viewed. Table 1 presents five widely used definitions of digital innovation.

Definition	Source
"a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT"	Fichman et al., 2014, p. 330
"the recombination of digital components in a layered, modular architecture to create new value-in-use to users or potential users of a service"	J. Huang et al., 2017, p. 302
"the creation or adoption, and exploitation of an inherently unbounded, value-adding novelty (e.g., product, service, process, or business model) through the incorporation of digital technology"	Hund et al., 2021, p. 6
"the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology"	Nambisan et al., 2017, p. 224
"new combinations of digital and physical components to produce novel products"	Yoo et al., 2010, p. 725

Table 1: Definitions of Digital Innovation

While Fichman et al. (2014) describe digital innovation in terms of the actual outcome of the innovation process, the other definitions center on the underlying activity. All definitions integrate (1) the role of digital technologies and (2) the novelty of the innovation outcome as central aspects of digital innovation (Fichman et al., 2014; J. Huang et al., 2017; Hund et al.,

2021; Nambisan et al., 2017; Yoo et al., 2010). Hund et al.'s (2021) definition synthesizes all the other definitions and is thus the most comprehensive; this dissertation therefore adopts this understanding of digital innovation.

Digital innovation exhibits three key characteristics: reprogrammability, homogenization of data, and self-reference (Hund et al., 2021; Yoo et al., 2010). First, reprogrammability refers to the inherent capability of digital innovations to perform various functions depending on the users' needs and wishes (Hund et al., 2021; Yoo et al., 2010). Second, the homogenization of data concerns the standardization of data formats in the digital realm. Regardless of the data content (e.g., video, audio, or text), all data is ultimately represented through sets of bits (Yoo et al., 2010). Therefore, almost all types of digital content are accessible through the same kinds of digital devices (e.g., smartphones and laptops) (Hund et al., 2021; Yoo et al., 2012). Lastly, self-reference describes the positive network externalities that digital innovation creates (Yoo et al., 2010). People must use digital technologies to use a digital innovation outcome (e.g., smartphones, computers) (Yoo et al., 2010). Consequently, they gain knowledge about digital technology usage, which improves and eases the creation of new digital innovations (Hund et al., 2021).

Throughout the years, a few central research themes have emerged in digital innovation research: (1) the blurring of boundaries, (2) digital systems, (3) digital strategy, (4) organizational determinants, and (5) arising tensions (Hund et al., 2021). To demonstrate the variety of topics discussed in digital innovation research, as well as underscore the socio-technical focus, the key themes are presented below.

The three characteristics of digital innovation lead to the dissolution of traditional boundaries, for example, in terms of products, roles, and organizations (Hund et al., 2021). With regard to products, digital innovations have a dual role. They can be the main "standalone" product or can enable the usage of additional products. For example, a smartphone is a product with value to users, but it also serves as a platform for using additional apps that provide value. Consequently, the definition of what constitutes the product (in this example, the smartphone or the app) becomes less clearly defined in the digital realm (Hund et al., 2021; Lusch et al., 2010; Yoo et al., 2010). Role boundaries change in the digital world as work and private lives are more heavily connected through digital innovations. The risk of feeling a constant need to be reachable, even after work hours, leads to blurred boundaries between work and private lives and is a prominent topic in technostress research (Lanzl, 2023; Ragu-Nathan et al., 2008;

Tarafdar et al., 2007). Lastly, organizational boundaries blur as novel digital innovations foster a closer, organization-independent collaboration and co-creation (Hund et al., 2021; Lyytinen et al., 2016). Associated research concerns the effects of blurring boundaries on people and their health (Lanzl, 2023; Ragu-Nathan et al., 2008; Tarafdar et al., 2007), new forms of cross-organizational or cross-industry collaborations (Lyytinen et al., 2016), or novel forms of product and service portfolios (Herterich et al., 2023; Lusch & Nambisan, 2015).

Blurred organizational boundaries imply that digital innovation is no longer an individual product or process that can be researched in isolation. Instead, digital innovation research pays special attention to digital systems and the interdependence between various stakeholders involved in digital innovation (Hund et al., 2021). Digital systems comprise digital infrastructures, digital platforms, and ecosystems (Hund et al., 2021; Tilson et al., 2010; Tiwana et al., 2010). Specific topics of concern are collaboration structures in innovation ecosystems (Costabile et al., 2022; Eckhardt et al., 2021; Herterich et al., 2023), value-creating mechanisms on platforms (Bonina, Koskinen, et al., 2021; Keijzer-Broers & de Reuver, 2016; Ravishankar, 2021), and the role of digital infrastructures in driving innovation (Furstenau et al., 2016; Hanseth & Lyytinen, 2016; Seshadri et al., 2020).

Digital innovation also leads to new types of collaboration and co-creation, thus blurring organizational boundaries, and the implementation of new types of technologies. As a result, organizations active in digital innovation must adapt their strategies to innovation's changing and dynamic nature (Hund et al., 2021). Research on digital strategies analyzes the shift from top-down to bottom-up strategizing (Arvidsson & Mønsted, 2018; Vega & Chiasson, 2019), adaptations to strategic partnerships (Arakji & Lang, 2007; J. Huang et al., 2017), and the development of dedicated digital business strategies (Bharadwaj et al., 2013; Hanelt, Bohnsack, et al., 2021).

The last two research themes in digital innovation research surround organizational determinants for successful innovation and tensions in leveraging digital innovation (Hund et al., 2021). Regarding organizational determinants, several digital capabilities are required for digital innovations, such as agility, ambidexterity, and dynamic capabilities (Karimi & Walter, 2015; Stelzl et al., 2020; Tallon et al., 2019). In addition, organizations need to transform their organizational structure to account for distributed innovation agency and novel forms of collaboration within networks (Berente, 2020; Hund et al., 2021; Lyytinen et al., 2016). On the social side, building a digital identity and culture is a relevant organizational determinant (J.

Huang et al., 2017; Lokuge et al., 2019). When pursuing digital innovation endeavors, several competing concerns or paradoxes can arise (Hund et al., 2021). For example, organizations struggle with the simultaneous necessity for both stability and flexibility or the need for decentralized autonomy while also maintaining centralized governance structures (Nambisan et al., 2019; Tilson et al., 2010).

In summary, digital innovation research integrates a variety of topics with both technical and social foci. Existing research themes not only consider digital innovation outcomes (e.g., digital systems, blurring product boundaries) but also extend to the preceding actions (e.g., cross-industry collaboration, capability building) and the surrounding environments (e.g., digital culture and strategy) (Hund et al., 2021). This dissertation builds upon the broad knowledge base on digital innovation (e.g., Drechsler et al., 2020; Hund et al., 2021; Kohli & Melville, 2019). In particular, the socio-technical understanding of digital innovation systems as a set of digital innovation actions reciprocally interacting with the digital innovation environment to create digital innovation outcomes serves as the foundation of all subsequent chapters on a macro-level (Kohli & Melville, 2019). The chapters analyze the dynamics of digital innovation actions, environments, and outcomes in more detail.

2.2 Digital Innovation for Sustainability

Digital innovation aims at creating novel value (Hund et al., 2021). Value, however, can have many forms. In digital innovation research, the majority of studies consider economic value, for example, in the form of profitability, new markets, or increased customer satisfaction (Fichman et al., 2014; Hanelt, Firk, et al., 2021; Lyytinen et al., 2016). Digital innovation also has the potential to create social and environmental value – the other two pillars of sustainability (Amenta et al., 2021; Bähr & Fliaster, 2023; George et al., 2021). Together, economic, social, and environmental sustainability form the triple bottom line (TBL) of sustainable development (Dao et al., 2011; Elkington, 1997).

A sound understanding of the many facets of sustainability is essential to determining the value of digital innovations in terms of the TBL. The 17 UN SDGs are a popular tool for specifying the sub-goals of economic, social, and environmental sustainability (United Nations, 2015). The 17 SDGs are presented below in Table 2. Some SDGs clearly fall beneath one of the three pillars. For example, Good Health and Well-Being is one aspect of social sustainability; Climate Action belongs to environmental sustainability; and Industry, Innovation, and Infrastructure is

part of economic sustainability (Delli Paoli & Addeo, 2019; Kuźniarska et al., 2024). Other SDGs address multiple pillars. Sustainable Cities and Communities, for example, include social aspects such as safety as well as environmental aspects such as waste management or energy provision. This demonstrates the strong interdependence of the different dimensions of the TBL and is part of why sustainable development is so complex to achieve (Dao et al., 2011).

SDG	**Description (from United Nations, 2015)**
SDG1: No Poverty	End poverty in all its forms everywhere.
SDG 2: No Hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.
SDG 3: Good Health and Well-Being	Ensure healthy lives and promote wellbeing for all at all ages.
SDG 4: Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
SDG 5: Gender Equality	Achieve gender equality and empower all women and girls.
SDG 6: Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all.
SDG 7: Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all.
SDG 8: Decent Work and Economic Growth	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
SDG 9: Industry, Innovation, and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
SDG 10: Reduced Inequalities	Reduce inequality within and among countries.
SDG 11: Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable.
SDG 12: Responsible Consumption and Production	Ensure sustainable consumption and production patterns.
SDG 13: Climate Action	Take urgent action to combat climate change and its impacts.
SDG 14: Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.
SDG 15: Life on Land	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and biodiversity loss.

SDG	Description (from United Nations, 2015)
SDG 16: Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels.
SDG 17: Partnerships for the Goals	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

Table 2: The 17 United Nations Sustainable Development Goals

Sustainability and many of the corresponding sub-challenges are generally categorized as complex (also known as "wicked") problems (Lönngren & van Poeck, 2021; Metcalf & Benn, 2013). Ten guiding rules characterize such problems (Lönngren & van Poeck, 2021; Rittel & Webber, 1973a). For example, complex problems are unique and do not have definite endings (i.e., stopping rules) (Rittel & Webber, 1973a). In the case of sustainability and sustainable development, it is almost impossible to determine the point at which sustainable development has been fully achieved. Lastly, there is little possibility to immediately measure the effectiveness of solutions to complex problems (Rittel & Webber, 1973a). Instead, the quality of implemented solutions reveals itself after long periods.

Digital innovation carries substantial potential for contributing to sustainable development despite the associated challenges of the complex problems it poses (George et al., 2021). However, research that has extended digital innovation beyond economic sustainability is scattered across different outlets and disciplines and uses inconsistent terminology. Consequently, it is difficult to grasp, synthesize, and develop the existing contributions in digital innovation for sustainability. Table 3 presents an overview of the central concepts of digital innovation for sustainability.

The concepts presented in Table 3 all focus on the intersection between digitalization and sustainability but cover different subsets of topics. Energy informatics and Green IS are centered around environmental sustainability and have a stronger technical rather than innovation focus (Watson et al., 2010). Similarly, digital eco-innovation and green innovation refer to the environmental side of the TBL (Butler & Hackney, 2015). In contrast, ICT-enabled social innovation considers social sustainability only (European Commission. Joint Research Centre. Institute for Prospective Technological Studies., 2016). Lastly, digital innovation for sustainability, ICT-enabled sustainability innovation, and digital social innovation present the most comprehensive concepts as they comprise all of the TBL (Bonina, López-Berzosa, & Scarlata, 2021; Joukhadar et al., 2023). Of the three, digital innovation for sustainability is an

umbrella term for all research at the intersection of digital innovation and sustainability. In contrast, the terminology of ICT-enabled sustainability innovation has only been used a few times (Kurnia et al., 2019). Digital social innovation could be assumed to include only social sustainability given the terminology. Still, within the research stream, "social value" is defined as also including economic and environmental sustainability (Buck, Krombacher, et al., 2023).

Concept	Description
Digital eco-innovation	"the carrying out of new combinations of digital and physical components to produce novel, environmentally sustainable outcomes (products, services, business models)" (Hanelt et al., 2017, p. 493)
Digital green innovation	"the integration of digital technologies represented by 5G and the Internet of things into the current development of green innovation" (S. Yin & Yu, 2022, p. 2) Green innovation is seen as "the generation of new ideas, goods, services, processes, or management systems that can be used to deal with environmental problems" (Saunila et al., 2018, p. 631)
Digital innovation for sustainability/digital sustainability innovation	"a process where digital technology leads to innovation processes that facilitate sustainable development" (Joukhadar et al., 2023, p. 242)
Digital social innovation	"digital solutions to social challenges" (Bria, 2015, p. 4)
Energy informatics	"analyzing, designing, and implementing systems to increase the efficiency of energy demand and supply system" (Watson et al., 2010, p. 24)
Green IS	Green IS is "not limited to the energy efficiency and equipment utilization of IT, but focuses on the design and implementation of information systems that contribute to the implementation of sustainable business processes" (vom Brocke et al., 2013, p. 510)
ICT-enabled social innovation	"a new configuration or combination of social practices providing new or better answers to social protection system challenges and needs of individuals throughout their lives, which emerges from the innovative use of Information and Communication Technologies (ICTs)" (Misuraca et al., 2016, p. 10)
ICT-enabled sustainability innovation	"ICT-enabled innovations that improve organizations' TBL performance" (Kurnia et al., 2019, p. 2)

Table 3: Concepts Related to Digital Innovation in a Sustainability Context

This dissertation adopts the overarching term of digital innovation for sustainability as it covers all the other concepts and is thus the most inclusive. Sustainability is therefore understood as

addressing all three pillars of sustainability – economic, social, and environmental. Some of the individual chapters of this dissertation address all pillars simultaneously (e.g., Chapter 6). Other chapters are more focused on understanding digital innovation for one specific pillar of sustainability (e.g., Subchapter 3.1 or 4.1).

2.3 Research Methods in Information Systems and this Dissertation

As mentioned in Chapter 1, the transdisciplinary nature of IS research demands applying a wide range of methodological approaches to fully understand socio-technical phenomena (Friedrich et al., 2017; Hevner et al., 2004; Wilde & Hess, 2007). Research in high-quality IS outlets ranges from structured literature reviews (e.g., Hund et al., 2021; Kohli & Melville, 2019), empirical online experiments (e.g., Ben Mimoun et al., 2014; X. Tan et al., 2022), and action research (e.g., Avison et al., 2018; Davison et al., 2021) to design science-based prototyping (e.g., Hevner et al., 2004; A. S. Lee et al., 2015; Peffers et al., 2007). The right choice of methods is fundamental and strongly depends on the research question to be answered and the type of contribution sought (Constantinides et al., 2012; Gregor, 2006). Regarding theoretical contributions, Gregor (2006) outlines five types of theory in IS research, the methodologies used to create them, and their value for driving knowledge. The notion of theory is often blurry, but theories can generally be seen "as abstract entities that aim to describe, explain, and enhance understanding of the world and, in some cases, to provide predictions of what will happen" (Gregor, 2006, p. 616).

The five theory types, structured according to five levels, are (1) theory for analyzing, (2) theory for explaining, (3) theory for predicting, (4) theory for explaining and predicting, and (5) theory for design and action (Gregor, 2006). The first and most basic type of theory in IS is the theory for analyzing. The primary purpose of this theory type is to analyze and describe the phenomenon of interest and to offer insights on "what is" (Gregor, 2006). Theories for analyzing are instrumental when phenomena are new and not yet understood at all. Taxonomy development (e.g., Kundisch et al., 2022; Nickerson et al., 2013) and grounded theory approaches (Corbin & Strauss, 1990; Glaser & Strauss, 1967; Wolfswinkel et al., 2013) are methodologies to create classifications, frameworks, or categories as part of theories for analyzing.

The second level concerns theories for explaining (also referred to as theories for understanding) (Gregor, 2006). This theory type answers questions regarding why and how

exactly something has occurred (Gregor, 2006). Providing sufficient evidence to support the plausibility of the claims made and some degree of generalization are critical challenges for theories for explaining. Case studies (R. K. Yin, 1994), interpretive field studies, and surveys (Pinsonneault & Kraemer, 1993) are possible methodologies to create such theories.

The third level contains theories for predicting, which use a set of independent variables to predict the outcome(s) of the phenomenon under investigation (Gregor, 2006). However, these theories do not focus on finding explanations for the effects identified within the prediction models. Compared to research in finance or econometrics, the IS community rarely produces this type of theory. Moore's law is one of the few examples of IS theories that fits into this category (Gregor, 2006; Moore, 1965). On a methodological level, quantitative statistical approaches such as regression analyses and data mining are applied (Kleinbaum et al., 2010).

The fourth theory type, theory for explaining and predicting, synthesizes levels two and three (Gregor, 2006). This theory type includes the constructs, their relationships, and predictions on what will happen over time. IS theories on technology acceptance, such as the Technology Acceptance Model, are prominent representatives of theories for explaining and predicting (Davis, 1989). The value of these theories comprises both theory building and theory testing. All the methodological approaches mentioned for levels two and three can also be applied to theories at level four.

Lastly, level five includes theories for design and action (Gregor, 2006). This type of theory is fundamentally different from the other four levels in that it moves from descriptive knowledge to prescribing how to do something – in the case of IS research, how to develop IS artifacts (Gregor, 2002). In general, descriptive knowledge (resulting from level 1–4 theories) contains information about natural phenomena or human behavior and advances our understanding of how the world works (Baskerville et al., 2018; Hevner, 2021). It combines classifications, observations, and measurements of such phenomena with sense-making of the dependencies between phenomena through natural laws, principles, or patterns (Baskerville et al., 2018; Gregor & Hevner, 2013; Hevner, 2021). In contrast, theories for design and action yield prescriptive knowledge, which explains how to build human-made artifacts (Gregor & Hevner, 2013). Such knowledge aims to improve humans' capabilities to develop practical artifacts (Baskerville et al., 2018). Within this theory type, action research or design science is used to create constructs (i.e., concepts, symbols), models (i.e., representations, semantics/ syntax),

methods (i.e., algorithms, techniques), and implementations (i.e., systems, products/ processes) supporting systems design (Gregor & Hevner, 2013; March & Smith, 1995).

The differentiation between level 1–4 theories and level five theories also extends to the two fundamental research paradigms in IS research, namely behavioral science and design science (Hevner et al., 2004). Behavioral science generates descriptive knowledge (Hevner et al., 2004; March & Smith, 1995). This paradigm stems from the natural sciences and focuses on theory development and justification to "explain or predict organizational and human phenomena surrounding the analysis, design, implementation, management, and use of information systems" (Hevner et al., 2004, p. 76). Complementing the behavioral science paradigm, the design science paradigm originally came from the engineering sciences (Simon, 1980). The main focus of the design science paradigm is to solve problems by effectively and efficiently leveraging information systems development (Denning, 1997; Hevner & Chatterjee, 2010; Hevner et al., 2004). While they are generally perceived as two different paradigms, they are also interdependent in that knowledge from design sciences impacts the behavioral sciences and vice versa (Baskerville et al., 2018; Hevner et al., 2004; Wimmer & Yoon, 2017).

Much has been done concerning design knowledge in digital innovation for sustainability research. Researchers have predominantly reported on individual, design-based (case) studies of digital innovations for sustainability (e.g., Foster & Heeks, 2013; Gimpel et al., 2022; Keijzer-Broers & de Reuver, 2016). These studies have yielded valuable knowledge regarding designing digital innovations that have a sustainable impact. They have also demonstrated the potential of digital innovations for sustainability in diverse contexts (e.g., education, climate change, and health) (Arts et al., 2020; Maaravi & Heller, 2021; Meister et al., 2019). A better, more generalizable understanding of the social and technical dynamics in digital innovation for sustainability actions, environments, and outcomes is needed as a next step. Therefore, this dissertation aims to develop theoretical contributions at levels 1–4, namely for analyzing, explaining, and predicting (Gregor, 2006). Such knowledge belongs to the field of the behavioral science paradigm. Hence, this dissertation applies methodologies of that paradigm (Hevner, 2021).

Studies in both paradigms can apply qualitative, quantitative, or mixed-methods approaches (Venkatesh, Brown, & Sullivan, 2016; Wilde & Hess, 2007). In qualitative research, data in the form of words and language are gathered, analyzed, or developed to better understand the phenomena under investigation (Remenyi & Williams, 1996). The primary purposes of

qualitative research are identifying relevant constructs for a phenomenon, explaining observed relationships, understanding people's perspectives and contextual factors, and understanding the phenomenon's evolution over time (Kaplan & Maxwell, 2005). Research questions in qualitative research are mostly exploratory in that they aim to develop new theories rather than testing existing ones (Venkatesh, Brown, & Sullivan, 2016). The number of qualitative studies in IS research remains significantly lower than that of quantitative studies (Cecez-Kecmanovic et al., 2020). Qualitative research methods include interview studies, grounded theory, case studies, or action research (Glaser & Strauss, 1967; Kaplan & Maxwell, 2005; Remenyi & Williams, 1996; Wilde & Hess, 2007).

Quantitative research uses numbers and numeric approaches (Remenyi & Williams, 1996). Quantitative research aims to detect or validate relationships between the constructs (e.g., social actors, technology, and contextual factors) relevant to the phenomenon in focus (Williams, 2011). Unlike qualitative research, quantitative research questions are primarily confirmatory as they seek to test and validate existing (expanded) theories rather than create entirely new ones (Venkatesh, Brown, & Sullivan, 2016). One of the main challenges for quantitative research is providing enough evidence for the results' reliability, validity, and practical relevance (Boudreau et al., 2001; Sen et al., 2022). Quantitative research approaches include observational studies and survey research, including corresponding statistical techniques such as correlation or regression analyses (Williams, 2011).

Mixed-methods research is another category of research approaches in IS (Venkatesh et al., 2013; Venkatesh, Brown, & Sullivan, 2016). Studies in this category combine at least one qualitative approach with at least one quantitative approach. The value of this procedure is threefold. First, mixed-method studies can bridge the weaknesses of each individual approach through the strengths of the other (Venkatesh et al., 2013; Venkatesh, Brown, & Sullivan, 2016). Combining quantitative and qualitative approaches can transform the knowledge gained into so-called meta-inferences, which are "an integrative view of findings from qualitative and quantitative strands of mixed methods research" (Venkatesh et al., 2013, p. 25). Second, mixed-method research allows for the inclusion of both exploratory and confirmatory research questions within the same study (Venkatesh et al., 2013). Third, the diversity of knowledge created in mixed-method research leads to higher levels of divergent, contradictory findings (Tashakkori & Teddlie, 2010). Divergence challenges researchers to reevaluate their assumptions regarding the phenomena under investigation, which ultimately clarifies and strengthens the overall contributions (Venkatesh et al., 2013).

This dissertation includes studies with purely qualitative approaches and mixed-methods research to analyze the dynamics of digital innovation for sustainability. There are both qualitative and quantitative components within the categories of innovation actions, environments, and outcomes to leverage the complementary benefits of mixed-methods research (Venkatesh et al., 2013; Venkatesh, Brown, & Sullivan, 2016). Subchapter 3.1 applies a combination of online experiments and surveys on idea evaluation in the complex problem domain. It integrates quantitative statistical assessments for performance assessments with qualitative deep dives to better understand and explain the numerical results. Subchapter 3.2 builds on a structured literature review (vom Brocke et al., 2015; Wolfswinkel et al., 2013) and grounded theory analysis following Gioia et al. (2013). Grounded theory is a methodological approach that produces rigorous qualitative analyses for describing and explaining social phenomena (Corbin & Strauss, 1990; Glaser & Strauss, 1967). The Gioia method especially helps in detecting constructs for organizational, socially constructed processes based on qualitative data (Gioia & Chittipeddi, 1991; Gioia et al., 2013) and is well-established in IS research (e.g., Annosi et al., 2022; Haug et al., 2023; Herterich et al., 2023).

Subchapter 4.1 uses a Delphi study to develop and structure technostress prevention measures and assess their effectiveness for different technostress sources. Delphi studies leverage experts to solve problems (e.g., through issue identification and prioritization or concept development) and apply a structured communication process spanning multiple rounds of input and feedback (Okoli & Pawlowski, 2004; Skinner et al., 2015). Subchapter 4.2 is a typical mixed-methods research in which a qualitative market analysis of the role of digital technologies in reusable systems follows a survey-based quantitative pre-study. The pre-study is used for theory testing, in this case of the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003; Venkatesh, Thong, & Xu, 2016). The market analysis builds on elements from structured web analyses and coding techniques from grounded theory to derive practical knowledge from online sources (Amalia et al., 2020; Wolfswinkel et al., 2013).

Chapter 5 presents a multi-methods research (Venkatesh, Brown, & Sullivan, 2016). Here, different qualitative methods are applied within one chapter. A taxonomy development process (Kundisch et al., 2022; Nickerson et al., 2013) structures smart urban agriculture innovations through different dimensions and characteristics. Taxonomy development is a typical methodology for classifying socio-technical phenomena; the resulting artifact belongs to theories for analyzing (Gregor, 2006). Expert interviews with scholars and practitioners are

used to derive and validate readiness factors for smart urban agriculture, with the interview data coded with a pattern-inducing mechanism from grounded theory (Wolfswinkel et al., 2013).

Finally, Chapter 6 presents a research agenda for digital social innovation. A structured literature review is leveraged to capture existing knowledge in the field and derive research pathways (Boell & Cecez-Kecmanovic, 2015; Leidner, 2018; Webster & Watson, 2002). Again, the data drawn from the literature review was coded using techniques from grounded theory (Wolfswinkel et al., 2013), followed by expert interviews serving as a validating tool to sharpen the research agenda's relevance (Myers & Newman, 2007; Venable et al., 2016).

3 Actions of Digital Innovation for Sustainability

Organizations that pursue digital innovation for sustainability subsequently execute a number of different innovation actions (Kohli & Melville, 2019). To just name a few examples, organizations invest in idea exploration, prototyping, and scaling (J. Huang et al., 2017; Kohli & Melville, 2019; Oberländer et al., 2021). Within these actions, digital technologies can assume two roles: they can serve as a means to facilitate the actions themselves or they can be part of the resulting innovation outcome (Ciriello et al., 2018). Subchapter 3.1 analyzes the potential of crowdsourcing and LLMs in facilitating the actions of digital innovation for sustainability (digital technology as a means). Subchapter 3.2 focuses on the role of digital innovation within DTs and takes an organizational change perspective (digital technology as an end).

3.1 Analyzing the Potential of Crowdsourcing and Large Language Models in Innovation Contests

Many of the most pressing sustainability challenges belong to the class of complex problems (Lönngren & van Poeck, 2021). Complex problems share common characteristics: they are (from the current point of view) unique, and humankind has little experience with solving them (Rittel & Webber, 1973b). Even if solutions are implemented, it often takes years or decades until the solution quality becomes visible and measurable (Gimpel, Graf-Drasch, et al., 2020). Thus, complex problems require sophisticated problem-solving abilities and the development of innovative solutions. In addition, the involvement of a broad range of affected stakeholders is a critical factor for solving complex problems (Head, 2008). Online innovation contests are one tool used to foster innovative problem-solving by offering a platform that brings together people with different knowledge in order to develop solution ideas (Gimpel et al., 2023; Özaygen & Balagué, 2018). Here, digital technologies (i.e., the platform infrastructure) are used as a means to facilitate the digital innovation process. Such platforms often address complex problems and contain individual contests for different sub-problems. These sub-problems differ in their level of specialization and thus require different levels of expertise to solve them. We define the term specialization as the degree to which a contest's topic belongs to one particular, knowledge-intensive domain rather than a broad field of interest.

Online innovation contests are highly accessible to all types of stakeholders regardless of time or location. This often leads to an abundance of submitted ideas, resulting in the challenge of

idea evaluation (Blohm et al., 2013). There is vast agreement that expert juries are the most suitable decision makers in the absence of an objectively known solution quality (Blohm et al., 2016; Görzen & Kundisch, 2016; M. Klein & Garcia, 2015; Nagar et al., 2016). In this context, decision maker refers to the instance that evaluates the idea. However, the resource of expert juries is scarce and expensive, creating a severe trade-off between efficiency and quality of evaluations. This bottleneck is one of the central challenges of using innovation contests to solve complex problems (Nagar et al., 2016).

In this subchapter, we study two promising alternatives to expert juries: (1) crowdworkers and (2) LLMs. Crowdsourcing idea evaluations is an approach that has gained recognition in research and practice (e.g., Görzen & Kundisch, 2016; M. Klein & Garcia, 2015; P. R. Magnusson et al., 2016; Mollick & Nanda, 2016; Oosterman et al., 2014; Wimbauer et al., 2019). Crowds refer to the general public (or selected communities thereof) and do not require participants to possess specific skills or expertise, in contrast to expert juries. The term "wisdom of the crowd" describes the phenomenon where the average of seemingly uninformed individual opinions can lead to collective intelligence when they work together as a group (Mollick & Nanda, 2016). Existing research compares crowd and expert idea evaluations in mainly corporate contexts and finds mixed results (P. R. Magnusson et al., 2016; Wimbauer et al., 2019). Yet, most corporate idea evaluations do not belong to the class of complex problems for two reasons: (1) idea quality can often be determined quickly in corporate environments and (2) specialized knowledge is often not required as the specialization of corporate problems typically is low (P. R. Magnusson et al., 2016; Wimbauer et al., 2019). So far, research has not investigated the potential of crowdsourced idea evaluations in contexts with nontransparent solution quality and varying specialization.

Coming to the second approach, evaluation tasks can be automated through AI (Nagar et al., 2016). For instance, Nagar et al. (2016) apply a computational approach where a machine learning classifier analyzes different characteristics of texts to assess ideas. However, the decisions of these models are based on various parameters (such as the length of the text) and are not based on knowledge about the content of the texts to be evaluated. Currently, a promising AI-based approach for evaluation tasks are LLMs, which gained significant recognition with the release of ChatGPT at the end of 2022 (Gao et al., 2023; J. Wang et al., 2023). Initial research on the capabilities of LLMs focuses on simple evaluation tasks such as stance detection or emotion recognition (Kocoń et al., 2023; B. Zhang et al., 2022). Some of the related studies show that LLMs also have the ability to execute various tasks for which they

were not initially trained (Kocmi & Federmann, 2023). Due to this ability, LLMs may be promising for idea evaluation. However, previous research on LLMs' capabilities incorporates neither complex problems nor specialized knowledge in detail.

Complex problems are specialized by definition, and specialization could push decision makers to their limits given their unfamiliarity with many sustainability topics. For effectively using crowdsourcing and LLMs in innovation contests, an assessment of the impact of specialization on idea evaluation quality is thus urgently needed. We need to understand which decision makers can be used best in which settings in order to maximize the utility of digital innovation contests for sustainability. Therefore, we address the following research question:

What is the potential of crowdsourcing and LLMs for evaluating solution ideas for complex problems in the presence of specialization?

To answer this question, we compare crowd and LLM evaluations of 104 ideas with four different levels of specialization hosted by the platform MIT Climate CoLab with expert evaluations. Our results show that depending on the specialization crowds and LLMs have the ability to evaluate ideas in the complex problem domain. Contest specialization is a key inhibitor of crowd performance that we can counteract by adapting the evaluation procedure. In contrast, we find that LLMs can better handle different degrees of specialization and yield higher performance when using ranking tasks.

3.1.1 Theoretical Background

Evaluating Solution Ideas for Complex Problems

Complex problems such as climate change, often also referred to as "wicked problems" are described as "complex, involving multiple possible causes and internal dynamics that could not [be] assumed to be linear, and have very negative consequences for society if not addressed properly" (Peters, 2017, p. 385). There is no clear path to solving these problems. However, a few principles guide the continuing efforts: (1) the need for coordination across locations, (2) the need to involve stakeholders from all types of interest groups, and (3) the need for a high degree of specialized knowledge (Head, 2008; Karvonen & Brand, 2009; Stern, 2006). Complex problems can be addressed through ideas and innovation – the central factor for solving problems (von Hippel, 1994).

To facilitate idea generation, the concept of IT-enabled idea crowdsourcing has emerged (Y. Han et al., 2020). Crowdsourcing generally describes open calls for contributions for selected

activities to benefit from human collective intelligence and allows for integrating a diverse crowd with different specialized knowledge, backgrounds, and experiences (Howe, 2006). Online innovation contests are a form of IT-enabled idea crowdsourcing that comprises idea generation and evaluation. With the often abundant ideas generated in innovation contests, the challenge of effectively evaluating and processing them arises (Blohm et al., 2013; Özaygen & Balagué, 2018). The characteristics of complex problems make their evaluation particularly difficult. To evaluate ideas, the decision makers judge ideas for complex problems based on their own experience and knowledge to make a qualified decision (Gerlach et al., 2019). Making this decision in highly specialized areas requires deep knowledge of specific domains (A. Fischer et al., 2012).

To approach idea evaluation in the light of complex problems, we refer to knowledge regarding idea evaluation in general. Researchers studied the evaluation procedure, with absolute rating and relative ranking being two of the best-known approaches. In absolute rating, the decision maker rates alternatives independently of each other, for example, on a Likert scale. In contrast, relative ranking describes decision makers' direct hierarchical arrangement of alternatives (Ovadia, 2004). Besides the evaluation procedures, researchers studied the different types of decision makers (e.g., expert juries, external crowds, and various technical solutions) (Blohm et al., 2016; M. Klein & Garcia, 2015; Nagar et al., 2016). Prior research suggests that expert juries generally outperform other decision makers and, thus, have been considered closest to the “ground truth” (Blohm et al., 2016; M. Klein & Garcia, 2015; Nagar et al., 2016). In contrast, crowds and technical solutions are more cost- and time-efficient than expert juries (Vukicevic et al., 2022). Consequently, idea evaluation is characterized by a trade-off between efficiency and quality. Therefore, to leverage the potential of digital innovation contests, the possibility of replacing expert juries with crowds or LLMs in a way that quality is not impaired has gained interest (Gao et al., 2023; Görzen & Kundisch, 2016; M. Klein & Garcia, 2015; P. R. Magnusson et al., 2016; Mollick & Nanda, 2016; Peres et al., 2023; J. Wang et al., 2023; Wimbauer et al., 2019).

Crowd-based Idea Evaluation

When a group of people, i.e. a crowd, evaluates ideas, the final evaluation results from an aggregation of all individual evaluations. Each individual evaluation of a crowdworker contributes to the creation of a larger, emergent value (i.e., the wisdom of the crowd) that is only realized through the synthesis of all contributions (Geiger et al., 2012). Several studies

analyzed replacing expert juries with crowdsourced idea evaluations, for example, in corporate innovation contests (Görzen & Kundisch, 2016; M. Klein & Garcia, 2015; P. R. Magnusson et al., 2016; Wimbauer et al., 2019) or evaluating projects in the arts industry (Mollick & Nanda, 2016; Oosterman et al., 2014). Generally, the results regarding crowd performance are mixed. Oosterman et al. (2014) see significantly better performance in expert juries on an image annotation task. On the contrary, several studies see congruence between expert and crowd evaluations and, thus, see high potential in crowd evaluations – at least for specific domains (P. R. Magnusson et al., 2016; Mollick & Nanda, 2016; Wimbauer et al., 2019). Groups tend to be more efficient for complex tasks than individuals (Almaatouq et al., 2020). To adequately address crowd evaluations and find generalizable results, an understanding of the underlying evaluation process is necessary.

In sum, existing research established crowd evaluations as a promising way to evaluate ideas (P. R. Magnusson et al., 2016). However, research has not yet investigated the potential of crowd evaluations under the consideration of contest specialization. While specialized knowledge has been mentioned as an essential factor for idea evaluation (Görzen & Kundisch, 2016), understanding its impact on crowd performance is still needed.

LLM-based Idea Evaluation

LLMs are computational models designed to analyze and generate text (Susarla et al., 2023). LLMs may rely on the Generative Pre-trained Transformer architecture, known for its "attention mechanism" (Vaswani et al., 2017). The attention mechanism enables the model to learn different positions of words in a sentence during the processing of input sequences by assigning individual weights to each element in the input, facilitating strong contextualization (Wolfram, 2023). Such models are pre-trained on extensive text datasets, creating a deep representation of the semantic structure of natural language. While LLMs yield promising results that are well-documented, the knowledge embedded in such models is broad and not task-specific. However, LLMs can be fine-tuned to specific tasks or domains and might be coupled with other knowledge sources such as knowledge graphs (Ray, 2023).

Several empirical studies have been conducted to investigate the capabilities of LLMs (Kocoń et al., 2023; B. Zhang et al., 2022). For instance, Kocoń et al. (2023) investigated an LLM's capabilities on 25 different natural language processing tasks, such as sentiment analysis, emotion recognition, and stance detection. Their study compares the LLM with the best existing task-specific automation solution. They showed that the LLM, on average, performed 25%

worse and concluded that the LLM can only cope with specific tasks to a limited extent. In contrast, B. Zhang et al. (2022) examine LLMs' capabilities in stance detection. In such tasks, a subject's standpoint (for, against, or neither) to a claim in a text is analyzed. The study found that the LLM can keep up with the performance of task-specific state-of-the-art solutions. Most studies have been in the zero-shot range, describing an LLM's ability to execute a new task without specific training (Ray, 2023). As existing studies demonstrated good LLM performance in zero-shot tasks, there are first indications that LLMs possess zero-shot qualities across domains (Kocmi & Federmann, 2023; Kocoń et al., 2023). In addition to zero-shot prompting, more complex prompting strategies, such as few-shot prompting and chain of thought prompting, can increase the quality of LLM output (Kocmi & Federmann, 2023).

Even though the examples above do not directly relate to the realm of idea evaluation for complex problems, they hint at LLMs' potential in this area. First, they show that LLMs can succeed in zero-shot tasks. Second, the natural language processing skills examined in these studies include both language understanding and language generation. These skills are required when evaluating solution ideas to understand the idea itself and to generate an evaluation. In addition, there is also research on LLMs' ability to evaluate text (Gao et al., 2023; Kocmi & Federmann, 2023; J. Wang et al., 2023). Prompting an LLM to rate the quality of text summaries from different datasets showed that an LLM can evaluate text and, in some instances, is closer to human expert juries than previous technological evaluation models (Gao et al., 2023). While this represents an important step towards leveraging LLMs for evaluation tasks, evaluating solutions for complex problems requires additional specialized domain knowledge (Karvonen & Brand, 2009). Investigating the potential of LLMs in this regard is essential because it may help close one of the most severe bottlenecks of innovation contests.

3.1.2 Theoretical Model

In this subchapter, we investigate whether crowds and LLMs can replace expert juries in idea evaluation for complex problems. Therefore, crowd and LLM performance is assessed as a measure of how similar the evaluation is to the expert jury's decisions. An expert jury's decision is not an objective measure of idea quality. However, in the absence of such a measure, the experts' assessment is as close to a ground truth as one can get (Blohm et al., 2016; M. Klein & Garcia, 2015). Our interest lies in analyzing the effect of contest specialization on evaluation performance and the evaluation procedure under which each decision maker can be utilized most.

Effect of Specialization

The type of task decision makers face strongly impacts their evaluation performance (Poole et al., 1985). Contest specialization is a relevant task characteristic because many topics addressed in innovation contests for complex problems are highly specialized and, thus, of little familiarity to a general crowd. For human decision makers, little familiarity with a topic indicates that individuals cannot use long-term memory resources to tackle a task and, thus, are bound to the restraints of the working memory (Kalyuga & Singh, 2016). Thus, high contest specialization increases the evaluation task's complexity (Song & Bruning, 2016). Consequently, higher complexity leads to worse performance by crowdworkers on a given task (Maynard & Hakel, 1997). This is caused by high complexity causing a mismatch between available information and task requirements in relation to one's available processing capacity (X. Cheng et al., 2020). We thus hypothesize:

H1a: For absolute rating, crowd evaluation performance is lower for innovation contests of higher specialization.

As seen in the H1a, our default for examining specialization is the absolute rating of ideas. This approach is also the default for LLM assessments. Generally, LLMs should be able to evaluate due to their ability in zero-shot range (Gao et al., 2023; Kocmi & Federmann, 2023; J. Wang et al., 2023). In addition, previous research also points to the ability to evaluate. Research is less clear regarding the relationship between contest specialization and the evaluation performance of LLMs. LLMs are trained on a large corpus of training data from a broad range of topics and, thus, possess a wide-ranging knowledge base that includes specialized knowledge in many different domains (Feuerriegel et al., 2023; Ray, 2023). With regard to complex tasks, the transformer architecture of LLMs enables them to process complex contexts through different weightings in the input – the attention mechanism (Vaswani et al., 2017). This is critical to an LLM's ability to answer specialized questions appropriately by considering the nuances of a specialized domain. Consequently, LLMs are probably familiar with highly specialized topics, and their evaluation performance does not depend on specialization levels. We thus hypothesize:

H1b: For absolute rating, LLM evaluation performance is not impacted by contest specialization.

Interaction Effect of Computed Ranking and Specialization

Hypothesizing the negative effect of specialization on crowd performance (H1a), the question of how do counteract this effect emerges. One possibility lies in specifically adapting the evaluation procedure to account for the challenges associated with high contest specialization. Absolute rating performance, as argued in the derivation of H1a, likely decreases with higher specialization. However, even if a decision maker evaluates several ideas independently on an absolute scale, the previous evaluations will subconsciously impact the subsequent evaluation scores (Mussweiler & Englich, 2005). In the field of decision-making, this effect is called anchoring or anchoring bias (Tversky & Kahneman, 1974), which, in our case, refers to the fact that the first proposals‘ evaluations influence the evaluation of subsequent proposals. The resulting subliminal comparison between proposals creates an implicit anchor that helps to decide what constitutes a good or a bad idea. By arranging the absolute evaluation scores from highest to lowest and making decisions based solely on the ranking position rather than the magnitude of the scores, a computed ranking is formed. This computed ranking allows for more consistent evaluations, as the individual evaluations are seen in a context of relative positions. We thus hypothesize:

H2a: Computed ranking reduces the negative impact of specialization on crowd performance as compared to absolute rating.

LLMs are not explicitly developed for evaluation but rather conduct the evaluation based on their broad language-based training data (Ray, 2023). These data included in the LLM provide an implicit anchor with which the ideas can be compared. When computing a ranking of the absolute ratings, differences between the individual proposals are presented in a more differentiated way, as they are not only considered in relation to the training data but also in relation to each other. Thus, a computed ranking should increase performance across tasks of every specialization. In line with our assumption in H1b, which posits that the evaluation performance is equal for varying degrees of specialization, we continue to not assume an interaction effect of computed ranking and specialization:

H2b: Computed ranking does not impact the effect of specialization on LLM performance.

Interaction Effect of Relative Ranking and Specialization

In addition to the computed ranking, relative ranking can be used to evaluate ideas. The computed ranking is based on sorting values that were rated on a scale independently. In

contrast, relative ranking describes the hierarchical arrangement of ideas (Ovadia, 2004). Research has found neither of the two approaches to be superior across use cases (Rankin & Grube, 1980). However, for crowdsourced idea evaluations, several studies indicated the superiority of relative ranking evaluations (Görzen & Kundisch, 2016; P. R. Magnusson et al., 2016; Mollick & Nanda, 2016). P. R. Magnusson et al. (2016) show that experts and crowds exhibit significantly higher evaluation conformance when using relative ranking. Rating of ideas requires individuals to create their own evaluation schemas and set their own boundaries for good and bad ideas. For relative ranking, the crowd does not need to know what ideas are on either extreme of a scale (Blohm et al., 2016). Instead, it is sufficient for crowdworkers to compare the available ideas regardless of where those ideas are placed in the complete spectrum of good and bad ideas. This suggests that the crowd performance could be improved when applying relative ranking in the presence of specialization. Hence, we hypothesize:

H2c: Relative ranking reduces the negative impact of specialization on crowd performance as compared to computed ranking.

To decide whether an idea is good or bad in absolute terms, an LLM must build an implicit hierarchy based on its knowledge base. To make the task easier for the LLM, users can request it to rank ideas (Ji et al., 2023). This provides the LLM with reference points for its decision. Reference points can be explicitly provided through pairwise comparisons – a form of relative ranking (Gao et al., 2023). Pairwise comparison is particularly suitable for LLMs, as a minimal context window is required. Due to the presence of more than one idea, the model does not have to compare the ideas solely to training data but has two ideas that it can compare. This should make it easier to evaluate the ideas leading to higher performance than the computed ranking. In line with our assumption in H1b, which posits that the evaluation performance is equal for varying degrees of specialization, we continue to not assume an interaction effect of relative ranking and specialization. We thus hypothesize:

H2d: Relative ranking does not impact the effect of specialization on LLM performance.

Figure 4 shows the resulting research model of this subchapter.

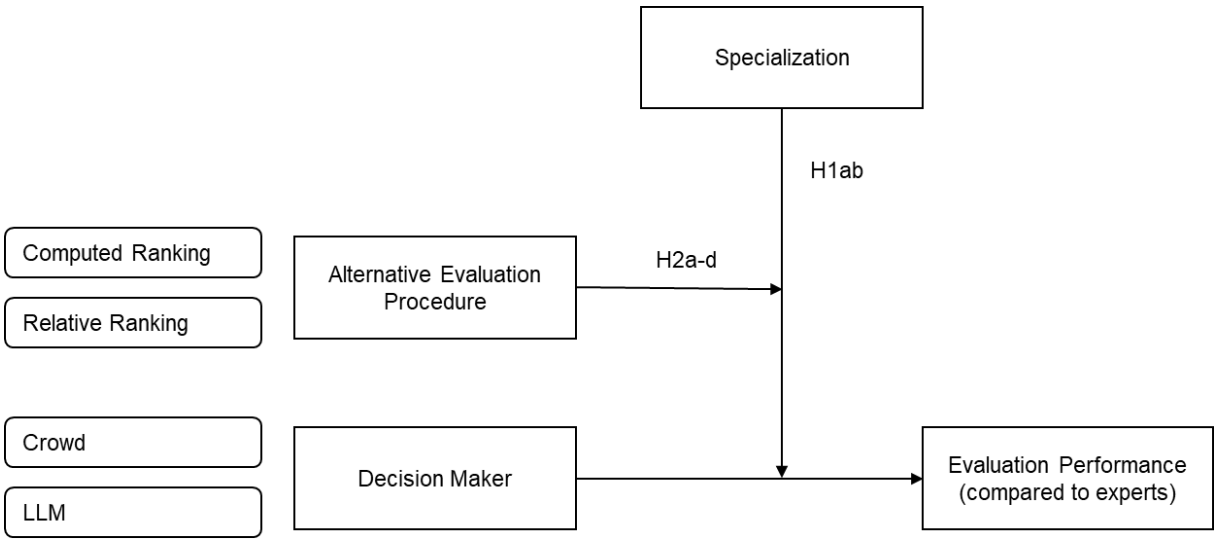


Figure 4: Research Model for Idea Evaluation in Innovation Contests

3.1.3 Research Methodology

To test our hypotheses, we use real-life ideas from innovation contests related to climate change submitted to a platform community called MIT Climate CoLab. On the platform, solution ideas are referred to as *proposals*.

Innovation Contest Context and Expert Evaluation

The MIT Climate CoLab is an open community platform aiming at tackling global climate change via innovation contests through the benefits of collective intelligence. The platform includes more than 125,000 participants who submit proposals and vote on ideas in contests addressing diverse facets of climate change. All proposals have the same basic structure and typically include a description of the suggested action, the expected impact, geographic restrictions, and investment needs. In contests, the semi-finalist and finalist selection are conducted by an expert panel of typically 2-5 scientists, policymakers, businesspeople, and investors in the decision-making process.

To compare the expert jury with crowd and LLM model evaluations, we selected completed contests and proposals hosted not later than 2018, containing at least 30 initial submissions and having detailed expert evaluations. Each contest portrays a sub-problem of the complex problem climate change (Peters, 2017). To assess each contest's specialization, we conducted a pre-test with nine researchers and five student assistants interested and knowledgeable in IT-enabled crowdsourcing and climate change. All participants independently ranked six contests

according to perceived specialization of the contests problem definition. They used the contest description and all the proposal titles as a basis for their decision. Intercoder reliability in the form of Kendall's coefficient of concordance is 0.79, indicating a strong agreement across raters (Kendall & Smith, 1939). The two contests with the highest and the lowest levels of specialization were selected for the subsequent analysis to best portray the extremes of low and high specialization. From lowest to highest specialization, the contests are titled as follows: (1) "Shifting Attitudes and Behaviors", (2) "Adaptation", (3) "Land Use: Agriculture, Forestry, Waste Management", and (4) "Energy Supply." These four contests represent our four different treatment groups, each of which differs in the specialization of the problem to be worked on. Since the four groups and the individual proposals are structured in the same way, the four groups differ only in the specialization of their content.

For the analysis, we selected the proposals and expert evaluations from the semi-finalist selection phase in each of the four contests. We selected this phase because the quality difference between the proposals is higher in this phase (as compared to the final), offering a better first data set for assessing the general potential of the two decision makers. Both proposals that advanced to the semi-final and those that did not were presented to the crowdworkers and the LLM for gathering evaluations. Overall, 26 proposals from each group (104 proposals in total) were presented in the evaluation task to the crowd and the LLM. The original expert jury was asked to evaluate proposals on the four dimensions of novelty, feasibility, impact, and presentation on a 4-point Likert scale as well as to decide whether they believed the proposal should advance to the next round on a 4-point scale (from "absolutely no" to "absolutely yes"). We refer to this overall quality indication as the decision makers evaluation score. We took the same approach for the crowd and the LLM. For each proposal, we assessed for each of the two evaluators if they agree with the expert jury on whether a proposal advances to the next competition round or not.

Crowd Evaluation

To collect crowd evaluations on the selected proposals, we used MTurk as a crowdsourcing platform. For IS research specifically, Jia et al. (2017) demonstrate the suitability of MTurk populations when conducting empirical studies. We recruited crowdworkers living in the United States to ensure English language proficiency (M. O'Leary et al., 2014). We further implemented validity indicators in the form of response time, response patterns, attention checks, and unusual comments to open questions (Jia et al., 2017; M. O'Leary et al., 2014).

Those who failed attention checks, had unrealistically short response time, or had invalid answers to the open question were marked as fraudulent.

Each crowdworker was presented six proposals from one of the four groups to evaluate the criteria presented above. In a second step, the crowdworkers had to rank the six proposals directly. We did this ranking task for two of the four groups. Proposals were randomly selected from the advancing and not advancing proposals groups and were shown in random order. Participants received a monetary reward of USD 3.60 for about 25 minutes of work. Prior research suggests that this moderate level of compensation is adequate on MTurk and encourages valid responses (Jia et al., 2017). In total, our data comes from 200 different participants. 57 participants were identified as fraudulent or bots based on the quality indicators and were thus removed from the dataset. This procedure resulted in 143 remaining participants.

LLM Evaluation

To generate evaluations from the LLM, we used the OpenAI Application Programming Interface (OpenAI, 2023). The GPT-3.5-16k model was used for the analysis. We used that model for two reasons: Firstly, the large context window of 16k tokens allows us to put in the lengthy proposals as a whole. Secondly, the knowledge base of this model (from September 2021) is close to the crowd data collection time which took place in 2020 which means that the LLM does not have a big knowledge advantage compared to the crowd.

In order to achieve the best possible output, we used various prompt engineering methods (OpenAI, 2024). For example, we assigned the persona of an expert to the LLM and made clear distinctions between different parts of the input (the evaluation task and the proposal). We iteratively developed the prompt until the LLM outputted the numerical evaluation of each individual criterion for the ideas (Kocoń et al., 2023). We used the same prompt for absolute rating and computed ranking. For relative ranking, we included the comparative component between two proposals. Appendix A.1 shows the final prompt for the absolute rating and Appendix A.2 shows the prompt for the relative ranking.

Since we are interested in the basic skills of the model, we left the temperature and all other parameters at their default values (Takagi et al., 2023). Optimization of such parameters could further improve the LLMs' performance. Thus, the results shown here should be considered a lower bound of the LLMs' evaluation potential. Two evaluation rounds were conducted. In the first round, each proposal was individually assessed 30 times based on the four evaluation criteria that the jury used and an overall evaluation score. This resulted in 780 evaluations per

group and 3,120 evaluations in total. In the second round, a pairwise comparison was conducted between all possible proposal pairs within each group (Gao et al., 2023). Since each group contains 26 proposals, 1,300 pair comparisons were conducted by the model. The cost of evaluating one proposal amounted to USD 0.02 for the LLM.

Evaluation Procedures

To examine specialization and the effect of different evaluation procedures on the effect of specialization, we used the following three evaluation procedures.

Absolute Rating: For the absolute rating, each decision maker was asked whether the proposal should advance to the final round on a scale from one (absolutely no) to four (absolutely yes). For absolute rating, we split the scale in half to classify proposals that received a mean rating below 2.5 as *not advance* and those 2.5 and above as *advance*.

Computed Ranking: For the computed ranking, we sorted all proposals by the average evaluation score from best to worst. We classified the best X proposals as *advance*, where X represents the number of proposals that the expert jury advanced to the next round.

Relative Ranking: For relative ranking, each crowdworker was shown six proposals with the task of ranking them from best to worst. This data was then used to calculate an average ranking for each proposal. The proposals were then sorted according to their average scores. We have implemented the relative ranking for the LLM by pairwise comparison of proposals. We sorted all the proposals based on the number of pair comparison wins from most wins to most minor wins. For both, we then classified the best X proposals as *advance*, where X represents the number of proposals that the expert jury advanced to the next round.

Performance Measurements

Our analysis assesses three performance measurements: balanced accuracy, the positive predictive value (PPV), and the negative predictive value (NPV) (Safari et al., 2015). We use *balanced accuracy* as an indicator for general performance of the decision maker, which is defined as the arithmetic mean of true positive rate (proportion of actual positives correctly classified) and true negative rate (proportion of actual negatives correctly classified). Balanced accuracy considers the class distribution and is useful when dealing with imbalanced datasets, which is the case for our sample (Brodersen et al., 2010).

The *PPV* reflects the decision makers' reliability when positively rating ideas. It is the number of proposals that the decision maker and the jury classified as *advance* divided by the number

of proposals the decision maker classified as *advance* (Safari et al., 2015). The *NPV* assesses how reliable the decision makers' negative evaluations are. It is calculated by dividing the number of proposals that the decision maker and the jury classified as *not advance* divided by the number of proposals the decision maker classified as *not advance* (Safari et al., 2015).

3.1.4 Results

Demographics and Descriptive Statistics

Of the 143 MTurk participants, 42% are female, 57% male, and 1% chose not to specify. On average, each MTurker spent 25 minutes on the crowdsourcing task. The LLM only takes 2 seconds to evaluate one proposal. For the crowd, we analyze the homogeneity of the participants concerning gender, age, education, and profession across the four groups to ensure comparability. For discrete variables, we use χ^2 tests for homogeneity, and for continuous variables, we use ANOVA (Hair et al., 2010). Based on those tests, participants do not differ significantly between the groups (5% significance level).

Next, we present descriptive statistics for the evaluations of the LLM. Figure 5 illustrates the distribution of the evaluation scores for each proposal across the four groups. The boxplots show the distribution of the 30 evaluation scores for each proposal. The black line represents the median, the black dot represents the mean, and the white dots show outliers.

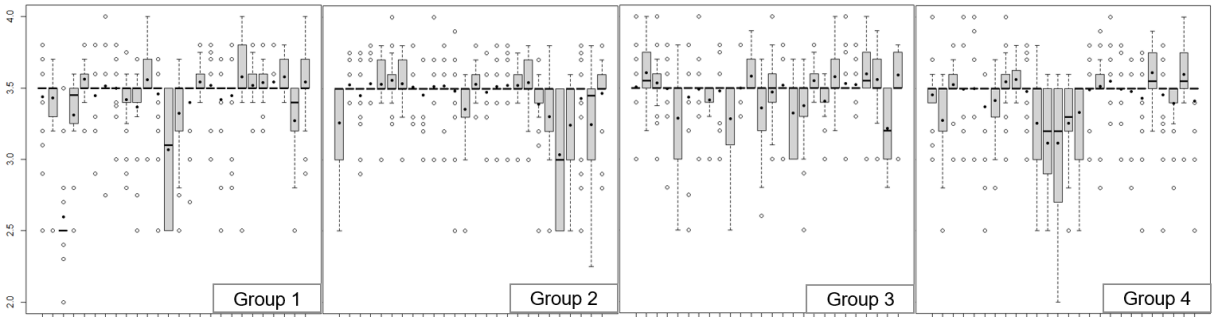


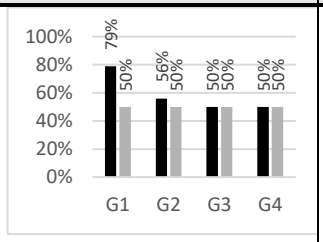
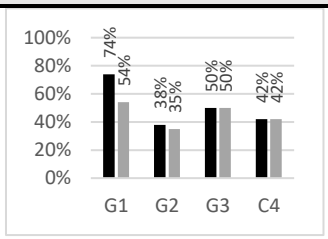
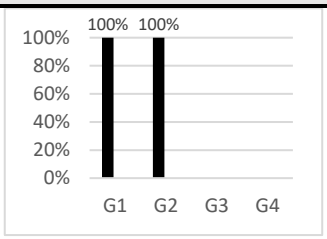
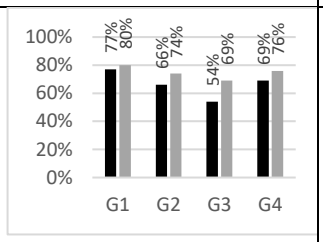
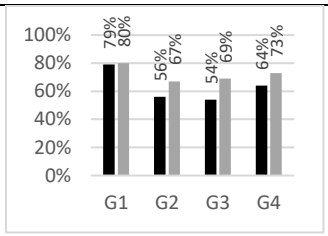
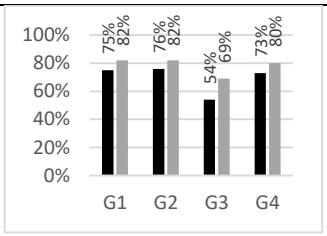
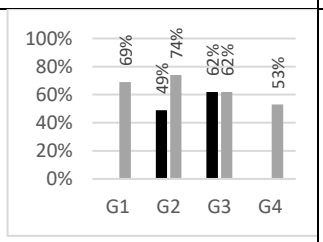
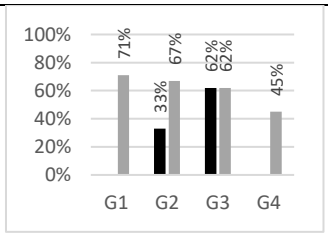
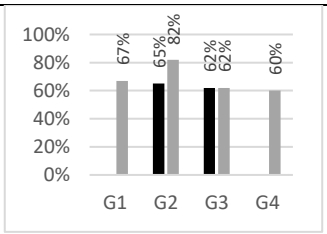
Figure 5: Boxplots of the Evaluation Scores of the Large Language Model

We can observe a strikingly low variance in the evaluation scores in the boxplots, with mean and median values clustered around 3.5. Thus, we conducted an ANOVA to find out whether significant differences exist between the mean evaluation scores of the proposals within each group. We conducted the ANOVA for each treatment group with 26 groups (since each group contains 26 proposals). Group 1 and 2 exhibit significant differences in their evaluation scores (p-value <0.05). Group 3 and 4 do not show significant differences in their evaluation scores, as their p-values are >0.05. However, the post-hoc Tukey test (Abdi & Williams, 2010) shows

significant differences between several proposals with regard to the mean evaluation scores for all four groups. This enables an interpretable ranking of proposals, demonstrating that the LLM does not rate all proposals equally.

Hypotheses Tests

Table 4 presents crowd and LLM performance measurements for each group's absolute rating, computed ranking, and relative ranking. Numerically, balanced accuracy is best for each group when using the LLM's computed ranking. Likewise, PPV is best for each group when using the LLM's computed ranking. For NPV, different combinations of evaluation metric and decision maker perform best.

Evaluation Procedure	Balanced Accuracy	PPV	NPV
Absolute Rating			
Computed Ranking			
Relative Ranking			

Black Columns: Crowd, Grey Columns: LLM

Table 4: Performance Measurements for Absolute Rating, Computed Ranking and Relative Ranking

To test the hypotheses, we use two statistical tests. First, we use Fisher's exact test to see if the performance in the groups changes significantly by changing the evaluation procedure. We conduct the test with two evaluation procedures as the rows of the 2x2 matrix, and proposals ranked identical as well as proposals ranked differently than the expert jury as its columns (Upton, 1992). Second, we use a χ^2 test for independence to see if there is a significant effect of specialization. The test is performed in a 4x2 matrix with the four groups of one evaluation

procedure as the rows. The two columns indicate whether a proposal was evaluated as identical or different from the expert jury as the second variable (McHugh, 2013).

Effect of Specialization on Absolute Rating Performance (H1a and H1b)

Assessing balanced accuracy values for an absolute rating of the crowd, we see a performance decline from the least specialized group 1 (79%) to the most specialized group 4 (50%). In group 1, the crowd rated ideas rather similar to the expert jury. With rising group specialization, the crowd's proposal evaluations differ more strongly from the experts. The resulting p-value of a χ^2 test for independence is 0.015, indicating that the groups' observed performance is significantly different between at least two of the groups. A pairwise comparison suggests that this is due to significantly higher performance in group 1 compared to the three other groups.

For absolute ratings, *advance* classifications by the crowd were more reliable for the little specialized groups as PPV decreases with group specialization. NPV values are at 100% for groups 1 and 2, indicating that all proposals the crowd rated negatively were also rated the same way by the expert jury. The crowd rated every proposal as advance for the two more specialized groups, which also explains the low PPV in those groups (not applicable (N/A) for NPV). Balanced accuracy and NPV both *support H1a*. The lower scores for PPV as compared to NPV indicate that the crowd a) tends to rate proposals too leniently and marks too many proposals as *advance*, especially in highly specialized groups. Also, b) the crowd is more reliable in their negative judgments.

Analyzing the balanced accuracy values of the LLM for absolute rating, we see a more consistent picture. Across specialization levels, we can observe a balanced accuracy of 50%. As the performance is constant, we conclude that it is independent of specialization, *supporting H1b*. NPV values for the LLM all show N/A. This results from the LLM marking every single proposal as *advance*. The PPV values are also influenced by the advancement of all proposals. Like the crowd, we observe that too many proposals are evaluated as *advance*. For absolute rating, LLM performance is rather poor, independent from group specialization.

Interaction Effect of Computed Ranking and Specialization (H2a and H2b)

The second set of hypotheses concerns the computed ranking process. For the *crowd*, we see a substantial performance increase for balanced accuracy with a delta of up to 19% (group 4) when shifting from absolute rating to computed ranking. Robust across all four groups, PPV values increase between 4% (group 3) and 22% (group 4) compared to absolute rating. In

computed ranking, the crowd's *advance* classifications become more reliable. For the less specialized groups, NPV performance decreases as the crowd rates more ideas as *not advance* with a few of them being false classifications. We conduct Fisher's exact test between absolute rating and computed ranking. Performance does not differ significantly between absolute rating and computed ranking (p-values from group 1 to 4: 1.000, 0.093, 1.000, 0.093).

Next, we assess the interaction effect of computed ranking and specialization. For the crowd, the impact of computed ranking on balanced accuracy is most minor for group 1 (-2%) and largest for group 4 (+19%). Accordingly, with higher specialization, the effect of computed ranking on crowd performance increases (χ^2 p=0.345), indicating that the performance is not significantly different between the groups. Consequently, by changing the evaluation procedure, the specialization effect disappears, which *supports H2a*.

When comparing absolute rating and computed ranking for the *LLM*, a clear increase in performance can be seen across all groups (delta between 19% for group 3 up to 30% for group 1). Fisher's exact test indicates that the distribution of equal and different ratings does differ significantly between absolute rating and computed ranking (p=0.075 for group 1, p=0.004 for group 2, p=0.023 for group 4, with one outlier in group 3: p=0.258). This increase is primarily because the LLM allows all proposals to advance in the absolute rating and is more nuanced in the computed ranking. PPV and NPV also show consistently high values across specialization levels. NPV values are the same or slightly higher than PPV (delta between 0% for group 3 up to 15% for group 2). Thus, the LLM is more reliable in identifying bad proposals. Balanced accuracy for computed ranking is in a rather narrow range between 69% (group 3) and 81% (group 1) and not significantly different (χ^2 p=0.801) across the four groups. Overall, this means computed ranking increases performance across all groups but does not create an effect of specialization on performance, which *supports H2b*.

Interaction Effect of Relative Ranking and Specialization (H2c and H2d)

The last set of hypotheses concerns the relative ranking procedure. For the *crowd,* balanced accuracy for the relative ranking is 49% for group 2 and 62% for group 3. Since NPV is equal to or higher than PPV, the crowd is also more reliable in identifying poor proposals than good proposals in the relative ranking. The p-values of Fisher's exact test between computed ranking and relative ranking are 0.393 for group 2 and 0.779 for group 3, showing that the distribution of equal and different ratings does not differ significantly. The resulting p-value of a χ^2 test for independence of 0.779 shows that the observed performance is not significantly different

between the groups. Thus, as our results show no further increase in performance, but the specialization effect is also no longer present, *H2c is supported*.

For the *LLM,* balanced accuracy for the relative ranking ranges from 53% (group 4) to 74% (group 2). Analogous to the computed ranking, the NPV values are, on average, better than the PPV values. This means the LLM is also better at identifying poor proposals when applying relative ranking. The difference in balanced accuracy between computed and relative ranking is smallest for group 2 (0%) and highest for group 4 (-23%). The p-values of Fisher's exact test between computed ranking and relative ranking show that the distribution of equal and different ratings does not differ significantly (p-values from group 1 to 4: 0.532, 1.000, 0.771, 0.144). To examine the specialization effect, we conduct a χ^2 test for independence. The resulting p-value of 0.334 indicates that the groups' observed performance is not significantly different between the groups. Hence, the LLM's rating performance with relative ranking does not depend on specialization, which *supports H2d*.

Table 5 summarizes our hypotheses and the respective empirical results.

#	**Description**	**Empirical Results**
H1a	For absolute rating, crowd evaluation performance is lower for innovation contests of higher specialization.	Supported
H1b	For absolute rating, LLM evaluation performance is not impacted by contest specialization.	Supported
H2a	Computed ranking reduces the negative impact of specialization on crowd performance as compared to absolute rating.	Supported
H2b	The computed ranking does not impact the effect of specialization on LLM performance.	Supported
H2c	Relative ranking reduces the negative impact of specialization on crowd performance compared to computed ranking.	Supported
H2d	The relative ranking does not impact the effect of specialization on LLM performance.	Supported

Table 5: Overview of Research Hypotheses

Analysis of Differentiated Proposal Evaluations

To better understand the decision makers' reasons for advancing or not advancing a proposal, we perform a logistic regression of the relationship between the independent variables novelty, feasibility, impact, and presentation (measured on a 4-point Likert scale) and the binary dependent variable (0 for not advance, 1 for advance) (Winship & Mare, 1984). As the computed ranking leads to the highest accuracy values, we focus on this evaluation procedure. The assumptions for the logistic regression, particularly the multicollinearity between the independent variables, were checked. We fit 15 regression models in total: For each of the three decision makers, we fit one model per group and an additional overarching model integrating all data. Exponentiated coefficients are used for interpretation, indicating a change in odds (for assessing proposals as advance) when increasing the respective independent variable by one unit. McFadden's Pseudo R^2 is computed as a goodness-of-fit measure, where values around 0.3 represent strong model fit (McFadden, 1979). Table 6 presents the results. McFadden's Pseudo R^2 values are high (between 0.347 and 0.694) for the crowd and jury, indicating strong predictability of the decision makers' decision based on the four dimensions. The LLM values are lower (between 0.066 and 0.267), indicating only a moderate fit of the logistic regression model.

Decision Maker	Criterion	All	Group 1	Group 2	Group 3	Group 4
Crowd	Novelty	1.66*	2.02*	3.20*	2.17*	1.05
	Feasibility	1.67*	1.86*	0.68	0.73	4.17*
	Impact	1.69*	2.11*	1.81	0.88	2.56*
	Presentation	4.80*	3.89*	5.30*	8.35*	11.47*
	McFadden's Pseudo R^2	0.371	0.368	0.35	0.347	0.598
LLM	Novelty	1.74*	2.07*	1.53*	1.61*	1.47*
	Feasibility	1.57*	1.49	1.05	3.85	3.8*
	Impact	3.48*	3.18*	2.93*	2.88*	11.50*
	Presentation	4.85*	5.35*	2.56*	4.95*	6.42*
	McFadden's Pseudo R^2	0.145	0.169	0.066	0.147	0.267
	Novelty	3.54*	5.8*	2.05	5.31*	5.02

Decision Maker	Criterion	All	Group 1	Group 2	Group 3	Group 4
Expert Jury	Feasibility	2.59*	10.10*	2.41	1.61	1.12
	Impact	3.11*	9.58*	2.73*	3.90*	1.03*
	Presentation	4.20*	3.65*	3.36*	2.99	3.35*
	McFadden's Pseudo R^2	0.515	0.694	0.445	0.468	0.614

$*=p<0.05$

Table 6: Logistic Regression for Idea Evaluations

For regressions with all groups, all four dimensions significantly and positively impact the decision to classify a proposal as advance. Consequently, for the expert jury, the crowd, and the LLM, a higher evaluation in the individual dimensions leads to a higher probability of advancing the proposal. For the crowd, presentation impacts the decision substantially more than the other dimensions. When looking at the values for all groups of the LLM, presentation, and impact have a high impact, novelty, and feasibility, a minor impact. In contrast, the expert jury's regression coefficients are more balanced. Analyzing the individual group regression, an effect of specialization can be found for the crowd's evaluation behavior. The more specialized a group is, the more strongly the crowd bases their decision on the proposal presentation rather than impact, novelty, or feasibility. No specialization effects can be identified for the expert jury and the LLM.

3.1.5 Discussion

Theoretical Implications

Idea evaluation by expert juries is a severe bottleneck in innovation contests, as temporal and financial resources are often scarce. Consequently, we investigate the potential of crowd and LLM evaluations to relieve expert juries of the burden of evaluating solutions to complex problems.

Existing studies on *crowd evaluations* focused on specific idea domains mainly in a corporate setting, and their results regarding crowd performance were mixed (Görzen & Kundisch, 2016; M. Klein & Garcia, 2015). Mollick and Nanda (2016) highlight the importance of better understanding the circumstances under which the crowd is a suitable decision maker. This subchapter provides evidence that contest specialization is a key inhibitor of crowd performance. Our findings on lenient crowd evaluations and overscoring further indicate that

crowdworkers are hesitant to rate a proposal negatively. This effect is particularly strong with high contest specialization, where the presentation of a proposal appears to inappropriately outweigh other relevant characteristics. The crowd likely struggles to reject ideas when they lack the specialized knowledge required to understand what constitutes a good or a poor idea. For research, these contributions shed light on evaluation patterns in crowdsourcing and reveal a potential error source in crowdsourced idea evaluations.

In line with P. R. Magnusson et al. (2016), ranking compared to absolute rating can counteract the hesitancy to reject proposals, particularly in the presence of high specialization. Ranking takes the responsibility of rejecting a proposal away from the crowd, as the proposals are sorted in the order of their quality. Contest operators are then responsible for setting a threshold and making the final decision regarding advancing and not advancing ideas. Ranking thus reduces the burden of understanding what good and bad proposals constitute on a universal scale of all existing ideas in favor of a comparative approach between the specific ideas in the respective contest. Therefore, the approach appears promising and highly relevant for innovation contests in the complex problem domain. This highlights that contest operators can affect the crowd's ability to evaluate ideas based on an adequate evaluation procedure design. Our results show that which ranking approach is used is less relevant, as the performance does not differ significantly between the computed ranking and the relative ranking. The original assumption that relative ranking leads to better performance was not supported here. One possible reason for this could be that the subliminal comparison between proposals in the computed ranking is already sufficient to evaluate the proposals appropriately.

Most previous research on the capabilities of *LLMs* has been related to natural language processing tasks (Kocoń et al., 2023; B. Zhang et al., 2022) which we have now extended to a practical evaluation task in the area of complex problems. In line with studies of LLM performance in natural language processing tasks referring to evaluation (Gao et al., 2023; Kocmi & Federmann, 2023; J. Wang et al., 2023), we show that LLMs possess evaluation capabilities. First and foremost, the evaluation performance of LLMs seems independent of specialization for each evaluation procedure. This adds to the theoretical foundations of LLMs, showing their inherent capacity to incorporate a wide array of diverse specialized knowledge to carry out evaluation tasks effectively.

A second noteworthy finding is that the LLM in this subchapter tends to assign only very good ratings with minimal variance across proposals on an absolute scale. This suggests that scoring

proposals based on an absolute rating may not capture nuanced differences in task complexity and comprehension. At first sight, no clear threshold divides the evaluation scores into good and bad. Comparing the computed with the relative ranking, the LLM performs worse in relative ranking. As this difference has no statistical significance, we cannot say which ranking approach is superior. The computational complexity of the computed ranking is in the class of linear time (O(n)), while it is quadratic time ($O(n^2)$) for the relative ranking based on pairwise comparisons. This means that if proposals are compared in pairs, each proposal must be compared with each other and therefore the effort is higher than if you only evaluate a single proposal. For a large number of proposals, this might lead to favoring the computed ranking. Therefore, researchers in the field of LLMs should carefully consider adopting ranking approaches to gain more meaningful insights into the model's performance on different tasks.

Based on a logistic regression, we were able to untangle the basis on which the LLM makes its decision. The moderate fit of the regression models for the LLM shows that we can only explain a small part of the variance of the LLM's decision to advance proposals. LLMs, therefore, remain a kind of black box for us in their mode of operation (Feuerriegel et al., 2023). This finding underlines the importance of Explainable AI to better understand how AI models make decisions (Ray, 2023).

Synthesizing the implications of both decision makers, it can be concluded that crowds and LLMs have the ability to evaluate ideas in the complex problem domain. The performance of the LLM is not dependent on the degree of specialization. In contrast, it's a key inhibitor for the crowd, but it can disappear through the choice of evaluation procedures. Further analysis show that both decision makers evaluate the few very best and worst ideas most accurately. Therefore, they are particularly helpful in the preselection phase of innovation contests to weed out bad ideas and reduce the burden on expert juries.

Practical Implications

Several practical implications can be inferred from this subchapter. First, our results show that, in general, crowds and LLMs can be used as decision makers in innovation contests that address complex problems. However, the impact of specialization highlights the need for contest operators to know the specialization of the topic to be evaluated. If information on the specialization is available, a crowd can be used for the evaluation of less specialized areas. If the specialization is not known or critically high, an LLM evaluation might be a more suitable solution as it evaluates regardless of specialization levels.

Second, our findings on the effectiveness of ranking evaluation procedures serve as guidelines for designing evaluation procedures in innovation contests. Innovation contests should use ranking tasks rather than absolute ratings for both crowds and LLMs to achieve assessments closer to expert juries. This holds in particular for evaluations by the crowd in contests where the domain is highly specialized or specialization levels are unknown.

Third, we observe that the presentation of the proposals strongly impacts the decision maker's decision to advance a proposal, particularly for the crowd. This finding could be considered when designing the platform by pointing idea generators to the importance of the presentation and standardizing the presentation's level of detail and professional appearance. Further, the crowd might be explicitly informed not to overly focus on the presentation of a proposal but to focus on aspects such as novelty, feasibility, and impact.

The fundamental challenge of balancing efficiency and quality cannot be solved entirely. However, our results suggest that when an expert jury is not available and the stakes in the decision are not too high, employing LLMs rather than a crowd might be appropriate. We specifically point to LLMs here rather than a crowd as — considering the numerical values of balanced accuracy — the computed ranking from the LLM outperforms other metrics and the crowd (the outperformance is numerical but not statistically significantly different from zero in all cases). The LLM evaluation quality tends not to deteriorate with contest specialization, and — given some technical expertise for assessing an LLM — evaluation is quicker and cheaper with an LLM as compared to a crowd. Further, GPT-3.5 allowed us to achieve roughly 70%-80% balanced accuracy compared to the expert jury. Using GPT-4 or other more advanced models that will become available over time will likely increase accuracy. A final word of caution: for high-stakes decisions, 80% accuracy might not suffice, and expert juries might be preferable.

Limitations & Future Research

Our research has limitations, which highlight the need for future research. First, the evaluation of the crowd took place in 2020, and the knowledge base of the LLM extends to 2021. In this period, there might have been technological or political progress in some of the idea areas discussed in the innovation contests. Consequently, these differences may impact the perception of an idea.

Second, our research builds upon the core assumption that expert jury evaluations are closest to the unknown ground truth of idea quality. Accordingly, we assess the decision makers'

performance by comparing their evaluation decision to the expert jury. This assumption is based on extensive research in the domain (Blohm et al., 2016; M. Klein & Garcia, 2015; Nagar et al., 2016). However, to fully validate this assumption and better understand the decision makers' evaluation behavior, it would be beneficial for future research to track the implementation progress and resulting benefits of the evaluated ideas. Similar to Wimbauer et al. (2019) research could then assess their actual quality and, even better, evaluate the idea preferences of the decision makers.

Lastly, after demonstrating the general suitability of LLMs in the complex problem domain, we offer pathways for improving evaluation performance. Further research should investigate more complex prompting strategies to achieve higher-quality output. In addition to adapting the prompting, fine-tuning an LLM to the specific task and knowledge area is possible to achieve better performance.

Conclusion

Designing idea evaluations in digital innovation contests for complex problems more efficiently is increasingly important, as traditional expert juries often constitute a severe financial and temporal bottleneck. This subchapter provides the first detailed assessment of the potential of crowdsourced idea evaluations and LLMs' idea evaluations in the complex problem domain. Our results suggest that specialization and evaluation procedures affect the crowd's potential across contexts and domains. With regard to the LLM, our results show that it can process tasks even in the zero-shot range, regardless of specialization. Overall, crowdsourcing and LLMs appear as two examples for how digital technologies can serve as a means to facilitating digital innovation actions in sustainability contexts. In the design of digital innovation actions, a match between the social and technical components and their strengths and limitations becomes inevitable.

3.2 Understanding Change in Digital Transformation

Next to leveraging digital technologies as a means, organizations have the opportunity to develop digital innovations (as an end) that contribute to sustainable development. However, the respective digital innovation actions are rarely an isolated endeavor. Rather, they are embedded in the overall digital transformation of an organization (Kaganer et al., 2023; Vial, 2019). Therefore, a successful DT is critical for adequately managing digital innovation for sustainability. Digital transformation has been intensively discussed in IS research (e.g., Hanelt,

Bohnsack, et al., 2021; Vial, 2019) and practice (e.g., Fitzgerald et al., 2013; Westerman et al., 2014) for over a decade. With reported failure rates beyond 80 percent (Wade & Shan, 2020), however, substantial barriers remain in the way of achieving higher DT success rates (Carroll, Hassan, et al., 2023; Rowe, 2018). Such barriers not only concern that DT is a complex, multilevel phenomenon (Iden & Bygstad, 2024), but also a missing awareness of what constitutes DT and how the associated change affects the organization at different levels of analysis (Soluk & Kammerlander, 2021; Taheri et al., 2022; Tijan et al., 2021). To address these barriers and increase the chances of success, a clear understanding about *what* changes throughout DT and *how* organizational change unfolds in the context of DT is necessary (Chanias et al., 2019; Hanelt, Bohnsack, et al., 2021; Vial, 2019).

Currently, there are wide disparities in the debates on which types of change exist in DT. This is an issue, because different types of change require different handling. One common view in the IS community is that DT is a source of continuous change (i.e., ongoing, evolving, and cumulative change) (Weick & Quinn, 1999), through which organizations continuously transform and adapt to changing market conditions (e.g., Chanias et al., 2019; Vial, 2019; Warner & Wäger, 2019). In contrast, other studies follow the punctuated equilibrium paradigm (Lyytinen & Newman, 2008; Sabherwal et al., 2001) and view DT as an episodic change process that includes radical and incremental changes (e.g., Drechsler et al., 2020; Fuchs & Hess, 2018; Gregory et al., 2018; Piccoli et al., 2024). Still others do not commit to either paradigm, claiming that DT can occur continuously or episodically (S. Huang et al., 2024) or argue that it simultaneously comprises elements of both change types due to its uncertain boundaries (Hanelt, Bohnsack, et al., 2021).

One reason for the differing viewpoints might be that current research analyzes organizational change in DT from different perspectives. Some studies look at organizational change from an organization-wide perspective (e.g., Hanelt, Bohnsack, et al., 2021; Vial, 2019; Wessel et al., 2021) and analyze strategic building blocks of DT, such as large-scale agile transformations (e.g., Fuchs & Hess, 2018). Other studies focus on organizational change in specific areas of an organization, such as IT governance (e.g., Gregory et al., 2018) or IT architecture (e.g., Piccoli et al., 2024). Still others examine change at an even more granular level by analyzing concrete change initiatives in day-to-day operations of individuals (e.g., Hinsen et al., 2019; Iden & Bygstad, 2024; Mirbabaie & Marx, 2024). However, organizational change in DT simultaneously occurs within and across various levels of analysis and these different levels impact each other (Lanamäki et al., 2020). For example, change at the organizational level is

ultimately also triggered by actions of individual employees at the more granular levels (Lanamäki et al., 2020). Due to this complexity, the overall nature of change in DT is difficult to evaluate comprehensively from a single-level perspective (Findikoglu & Watson-Manheim, 2016; Iden & Bygstad, 2024; Oberländer et al., 2024).

Higher success rates of DT thus require more clarity regarding the nature of organizational change in DT. Therefore, a better understanding of *what* changes at each level and across levels in the context of DT is needed to conclude *how* organizational change unfolds from an intra- and inter-level perspective. From a theoretical point, such a multi-level perspective on organizational change in DT is particularly relevant to unite the diverging views in debates surrounding change in DT (M. Zhang & Gable, 2017) and for practitioners to successfully manage and sustain DT in the long-term (Hanelt, Bohnsack, et al., 2021). Against this backdrop, we ask:

How does organizational change unfold within and across levels of analysis in the context of digital transformation?

To answer this research question, the main goals of this subchapter are to understand *what* changes in the context of DT within and across levels of analysis, and to theorize about *how* change unfolds from an intra- and inter-level perspective. To integrate both perspectives (i.e., *what* changes and *how* change occurs) and account for the complex phenomenon of organizational change in the context of DT, we built a multi-level analysis framework that differentiates between three levels of analysis: the micro-level (i.e., individuals and/or teams), meso-level (i.e., departments), and macro-level (i.e., organization). Based on a structured literature review (vom Brocke et al., 2015; Wolfswinkel et al., 2013) and analysis following Gioia et al. (2013), we identify three change constructs: DT initiatives, DT patterns, and DT themes. These change constructs can be assigned to the micro-, meso-, and macro-levels of analysis and describe *what* changes are taking place at each level.

Subsequently, starting at the micro-level, we present evidence on *how* change occurs for individuals, departments, and the entire organization. We demonstrate that at the micro-level, DT initiatives follow either an episodic or continuous nature of change. With higher levels of analysis, change shifts towards a more hybrid and continuous nature due to aggregation and balancing effects. By merging these two perspectives (i.e., *what* changes and *how* change occurs), we are able to explain *how* change aggregates across the different levels of analysis and why organizational change is increasingly perceived as continuous upwards.

3.2.1 Theoretical Background

Organizational Change

Since the 1980s, there has been rich literature on organizational change, such as cultural change, IT-enabled transformation, or DT. Organizational change is seen as a "difference in form, quality, or state over time in an organizational entity" (van de Ven & Poole, 1995, p. 512). Traditional change research distinguishes between two paradigms regarding the nature of change: change that is episodic and change that is continuous (Krovi, 1993; Tushman & Romanelli, 1985; Weick & Quinn, 1999).

First, the episodic change literature views organizations as prone to inertia and rarely changing (Hanelt, Bohnsack, et al., 2021; Weick & Quinn, 1999). According to the punctuated equilibrium paradigm, episodic change processes involve alternating periods of stability and incremental change (state of equilibrium) and revolutionary periods of radical change (state of disequilibrium) (Besson & Rowe, 2012; Gersick, 1991; Lyytinen & Newman, 2008; Sabherwal et al., 2001). During periods of stability, organizations remain aligned with their deep structures and experience no or only incremental changes (Fuchs & Hess, 2018; Tushman & Romanelli, 1985). Therein, deep structures represent the fundamental, interacting, and aligned components (e.g., structures & processes) of a socio-technical system (Lyytinen & Newman, 2008; Sabherwal et al., 2001). When system change reaches a critical level, where internal structures and the changing environmental demands diverge to the point that organizational adaptation stalls (Weick & Quinn, 1999), organizations are urged to make radical changes and reform their deep structures (Lyytinen & Newman, 2008). Only then are they able to reach a new state of equilibrium (Lyytinen & Newman, 2008; Weick & Quinn, 1999). The change process unfolds in a planned, intentional manner, following the sequence of unfreezing (i.e., breaking up deep structures), transition (i.e., restructuring deep structures), and refreezing (i.e., embedding new structures) (Weick & Quinn, 1999). The transition from a long period of stability and incremental changes to a revolutionary period of radical change is driven either by occasional external changes to which the organization cannot incrementally adapt (e.g., political and legal factors, such as new taxation) or by mismatches between critical system elements such as people and technologies (Lyytinen & Newman, 2008; Sabherwal et al., 2001).

Second, the continuous change literature views change as a constant, i.e., an ongoing, endless series of small adjustments to organizational processes and structures at the surface (i.e., easily visible changes) (Brown & Duguid, 1991; Weick & Quinn, 1999). Continuous change "groups

together organizational changes that tend to be ongoing, evolving, and cumulative" (Weick & Quinn, 1999, p. 375). Unlike episodic change, continuous change is seen as emergent and determined by numerous small responses to "everyday contingencies, breakdowns, exceptions, opportunities, and unintended consequences" (Orlikowski, 1996, p. 65). The accumulation of small, continuous adjustments across organizational units can, over time, lead to substantial organizational changes (Weick & Quinn, 1999), which is why continuous change may seem small in a given period, but is not trivial (Staw, 1991). In continuous change processes aimed at reshaping surface structures, organizations do not face the challenge of unfreezing (i.e., breaking up) rigid structures from the outset. Rather, organizations follow the logic of freezing (i.e., pausing ongoing processes), rebalancing, and unfreezing (i.e., resuming processes after improvisation) in an evolutionary process that has neither a beginning nor an end (Orlikowski, 1996; Weick & Quinn, 1999). During continuous change, organizations can be seen as somewhat remaining in a stable equilibrium (i.e., a state of balance between opposing forces) that allows for continuous and reciprocal adjustments (L. H. Fischer & Baskerville, 2023).

Digital Transformation

Due to the rapid spread of digital technologies, tremendous change occurred in the past decades (Liang Li et al., 2018). This change is associated with the terms digitization, digitalization, and DT. While digitization describes the technical process of converting analogue information into digital formats (Negroponte et al., 1997; Yoo et al., 2010), digitalization refers to the embedding of IT components in a broader individual, organizational, and societal context (Legner et al., 2017; Lyytinen & Newman, 2008). The transformative impact of IT on organizations has long been recognized under the term IT-enabled transformation (Lucas et al., 2013; Wessel et al., 2021). IT-enabled transformation considers the role of an individual technology for internal processes of a single organization. In contrast, DT refers to a socio-technical phenomenon that implies changes across organizational boundaries (Wessel et al., 2021). In addition, IT-enabled transformation is concerned with supporting and enhancing existing value propositions and organizational identities, while DT focuses on the redefinition and novel creation of the two (Hanelt, Bohnsack, et al., 2021; Vial, 2019; Wessel et al., 2021). In this subchapter, we build on Hanelt, Bohnsack, et al.'s (2021, p. 1160) definition of DT as "organizational change that is triggered and shaped by the widespread diffusion of digital technologies. "

IS research agrees that IT-enabled transformations follow traditional episodic change models and evolve in alternating phases with long periods of stability and incremental adaptation and

periods of revolutionary change (Besson & Rowe, 2012; Gregory et al., 2018; Lyytinen & Newman, 2008). The question remains whether these established organizational change models are adequate to also explain the nature of organizational change in the context of DT (Hanelt, Bohnsack, et al., 2021). Due to the characteristics of digital technologies (e.g., generativity, malleability, and combinatoriality) (Yoo et al., 2010) and their pervasive and ubiquitous nature (Urbach & Röglinger, 2019; Warner & Wäger, 2019), change becomes an integral part of organizations during DT and inertia tends to erode (Hanelt, Bohnsack, et al., 2021; Kaganer et al., 2023). Organizations need to constantly adapt their structures, strategies, and business models to the ongoing environmental and technological changes (Bharadwaj et al., 2013; Yoo et al., 2010).

As a consequence, there is a lively debate regarding how organizational change unfolds in DT, with different lines of argumentation coexisting. Research argues that episodic change models, in which a new equilibrium is sought after a period of change, do not meet the requirements of business environments in DT, as digital technologies cause more rapid and frequent change and periods of stability are less likely (L. H. Fischer & Baskerville, 2023). According to Hanelt, Bohnsack, et al. (2021, p. 19), even episodic changes in the context of DT are no longer infrequent and do not necessarily end in a new era of stability but may *"cascade in unpredictable ways"*. In line with Hanelt, Bohnsack, et al. (2021), L. H. Fischer and Baskerville (2023) argue that a state of constant changeability within an unstable equilibrium is required. According to L. H. Fischer and Baskerville (2023, p. 634), an unstable equilibrium describes "a system that is so dynamic that stability can never be more than temporary". While large parts of the IS community view DT a source of continuous change (e.g., Vial, 2019; Warner & Wäger, 2019) there are also other perspectives (e.g., Drechsler et al., 2020; Fuchs & Hess, 2018).

When considering DT as a source of continuous change, some studies interpret "continuous" in the sense that there is no end state and DT on a high level of abstraction is an ongoing process, without specifying pace, scope, and intensity of any underlying changes (e.g., Vial, 2019; Warner & Wäger, 2019). Others associate the term "continuous" with an endless series of small adjustments with a low degree of change. Hinsen et al. (2019), for example, define DT as a form of continuous change that mainly takes place in small, day-to-day operations. In line with Hinsen et al. (2019), Jöhnk et al. (2022) identify specific DT initiatives to explain how organizational change in DT occurs through the ongoing combination of multiple day-to-day activities. While Hinsen et al. (2019) and Jöhnk et al. (2022) speak of organizational change in

DT as an endless series of small adjustments, Hanelt, Bohnsack, et al. (2021) or Vial (2019) also agree that the concept of continuous change generally applies to the phenomenon of organizational change in DT. However, their interpretation of "continuous" refers more to the overall transformation process with no end state.

Hanelt, Bohnsack, et al. (2021) argue that due to the characteristics of digital technologies, even episodic bursts lead to new phases of continuous change, thus also incorporating the perspective of episodic change while referring to a more continuous manner of change. Others do not consider change in the context of DT as continuous, neither in terms of day-to-day activities nor in terms of the overall transformation process. They follow the paradigm of punctuated equilibrium and view organizational change in DT as episodic (e.g., Drechsler et al., 2020; Fuchs & Hess, 2018; Gregory et al., 2018; Piccoli et al., 2024). Fuchs and Hess (2018), for example, interpret large-scale agile transformations (a part of their DT) as an episodic change process, consisting of multiple phases of radical and incremental change. They argue that moving from one phase to another appears to be a leap rather than a continuous process (Fuchs & Hess, 2018).

As the current streams of literature and their different perspectives show, the question remains how organizational change unfolds in the context of DT and whether the established models of organizational change are adequate to explain it.

Multi-level Theorizing

One reason for the differing views might be that current studies tend to analyze organizational change in DT from different perspectives (e.g. organization-wide or department-focused). Organizational change in the context of DT is a phenomenon that spans different levels of analysis – from profound changes that occur at the overall organizational level to a detailed plan and set of actions at the individual level (Iden & Bygstad, 2024; Kaganer et al., 2023; Oberländer et al., 2024). To account for the different levels of analysis within a phenomenon, research has yielded the approach of multi-level theorizing (M. Zhang & Gable, 2017). Multi-level theorizing aims to examine complex (IS) phenomena from multi-level perspectives (M. Zhang & Gable, 2017). M. Zhang and Gable (2017, p. 2) define a multi-level perspective as "an approach to theory development that considers the relevance of multiple levels of analysis", while a level of analysis refers to "the conceptual entity under theoretical and empirical investigation".

By analyzing multiple levels simultaneously, it becomes possible to identify complex relationships and interdependencies between levels and to draw conclusions about the entity as a whole. For example, multi-level theorizing makes it possible to understand how smaller changes at the individual level influence profound changes at the organizational level (Kouamé & Langley, 2018). One fundamental assumption of multi-level theorizing is that micro phenomena are embedded in macro contexts, and that macro phenomena often arise out of micro phenomena (Kozlowski & Klein, 2000). For example, Y. Sun and Bhattacherjee (2011) outline how in the macro-phenomenon of IT usage in organizations, the individual employees (micro-level) are dependent on and embedded in the macro context (e.g., organizational culture, management support). At the same time, IT usage at the macro-level arises out of many individual's decisions to use the respective IT system (Y. Sun & Bhattacherjee, 2011)

Findings that focus exclusively on higher-level perspectives (e.g., the macro-level) may be too superficial and trivial if they neglect the lower-level dynamics and interactions that led to the higher-level phenomenon (Kozlowski & Klein, 2000). By promoting such isolated findings, single-level perspectives not only lead to an incomplete understanding but also contradict the rationale of the cumulative IS research tradition. If only one level of analysis is considered within the overall system, predicting future developments becomes more difficult (Kozlowski & Klein, 2000).

Current research shows that organizational change in the context of DT is a complex phenomenon that also spans multiple levels of analysis (Oberländer et al., 2024). Oberländer et al. (2024), for example, investigate how digital ecosystems influence DT using multi-level theorizing as their theoretical lens. Similarly, P. Wang (2021) investigate the role of autonomous parties (e.g., organizations) for the higher-level overarching digital innovation ecosystem. In addition, Iden and Bygstad (2024) leverage a socio-technical perspective to analyze how employees and digital resources interact to generate organizational capabilities at a higher level. Lastly, Kaganer et al. (2023) assess the micro-foundations of organizations in tackling organizational inertia at higher levels. Therein, DT is a suitable phenomenon for multi-level theorizing. When explicitly researching organizational change at different levels of analysis and their interdependencies, a clear definition of the respective levels is crucial (Gersick, 1991; M. Zhang & Gable, 2017). Given the diversity of topics in IS, no unified definition of the levels of analysis exists. However, across topics, the notion of micro-, meso-, and macro-levels has been applied to differentiate the level of focus (Agarwal & Lucas, 2005; Findikoglu & Watson-Manheim, 2016; Jensen et al., 2009). This also extends to the specific

context of DT, where a differentiation between micro-foundations (e.g., individuals or routines) and macro-outcomes (e.g., societal or organizational goals) is common (Findikoglu & Watson-Manheim, 2016; Iden & Bygstad, 2024).

To specifically account for the relevant levels of analysis, we draw from existing conceptualizations (Iden & Bygstad, 2024; Kozlowski & Klein, 2000; Mirbabaie & Marx, 2024), differentiating the micro-, meso-, and macro-level (Cowen et al., 2022; Kouamé & Langley, 2018). Building on multi-level theorizing, we aim to build a multi-level analysis framework as a means to assess *what* changes *how* in DTs from an intra- and inter-level perspective.

3.2.2 Research Methodology

To address the research question, the main goals of this subchapter are to understand *what* changes in the context of DT within and across levels of analysis, and to theorize about *how* change unfolds from an intra- and inter-level perspective. We offer a multi-level perspective on DT that is based on a structured literature review (vom Brocke et al., 2015; Wolfswinkel et al., 2013) and the rigor criteria of Templier and Paré (2018) (cf., Appendix B.1), as well as an analysis following Gioia et al. (2013). We provide an overview of organizational changes in DT at the micro-, meso-, and macro-level of analysis, which serves as a springboard for theorizing on the nature of change in the context of DT. Figure 6 presents the two-step research design.

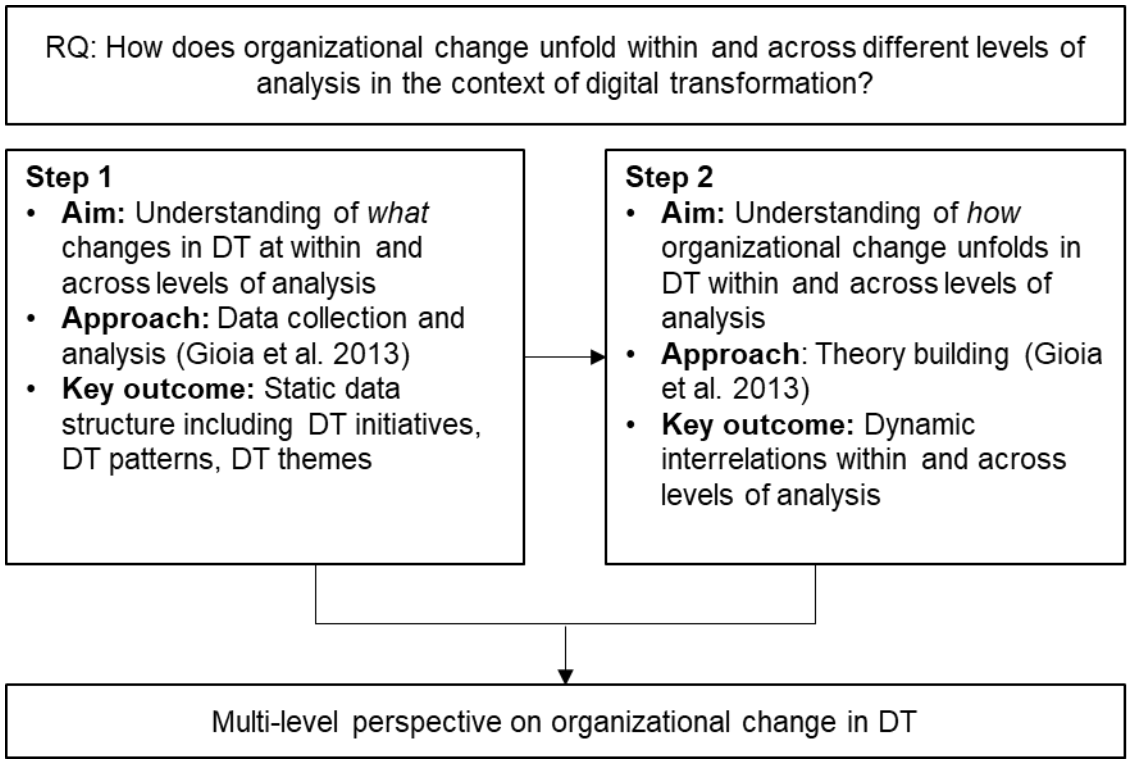


Figure 6: Research Design for Understanding Organizational Change in Digital Transformation

Data Collection and Analysis to Understand What Changes

In the first step, we thoroughly reviewed and synthesized the existing literature on DT to derive an understanding of the changes occurring in organizational DT. Given the broadness of a phenomenon like DT, the primary goal of this first step was not to be comprehensive across all disciplines and outlets, but rather "to make a large stream of literature understandable" (Leidner, 2018, pp. 554–555). The phenomenon of DT requires a socio-technical literature base, as it encompasses not only technical perspectives on digital change but also social ones (Datta, 2020). Opting for a specific stream, we chose to focus on IS literature due to its transdisciplinary nature and its consequential traditional focus on socio-technical change.

To include relevant research insights on organizational change in DT with a focus on both theory and practice, we systematically examined IS literature following the five steps of Wolfswinkel et al. (2013) from three vantage points: (1) high scientific rigor, (2) broad dissemination, and (3) renowned industry influence. To capture all relevant publications, we chose the simple search string "digital transformation". We applied this search string to the topic search within the following data sources: Senior Scholars' List of Premier Journals (for high scientific rigor) (Association for Information Systems, 2023), eLibrary of the Association for Information Systems (AIS) (for broad dissemination), and Harvard Business Review and

MIT Sloan Management Review (for renowned industry influence). To meet our inclusion criteria, a respective study must (1) focus on digital transformation, (2) investigate change in an organizational context, (3) refer to digital transformation as a socio-technical phenomenon, and (4) provide generalizable insights. A detailed overview of our inclusion/exclusion criteria can be found in Table 24 in Appendix B.1. Further, we only considered peer-reviewed articles and articles written in English within the AIS eLibrary. We initially obtained 314 articles, of which 120 articles originate from the Senior Scholars' List of Premier Journals, 153 articles from the AIS eLibrary, and 41 articles from Harvard Business Review/ MIT Sloan Management Review. After removing duplets, two co-authors each checked the relevance of the remaining 275 articles by analyzing their title, abstract, and keywords to assess whether a given article includes information on organizational changes in DT. Their assessment yielded a final data set of 142 articles (including 16 articles from forward and backward search) (Appendix B.2), each to be thoroughly analyzed with the data analysis tool MAXQDA. A detailed description of the five stages (i.e., define, search, select, analyze, and present) of the structured literature review can be found in Appendix B.1.

Following Gioia et al. (2013) for qualitative data analysis, we embarked on an iterative three-step coding process to derive change constructs (i.e., DT initiatives, DT patterns, DT themes) surrounding DT. We chose the approach of Gioia et al. (2013), as it ensures qualitative rigor in inductive research. During the coding process, we realized that the resulting coding structure represents a multi-level perspective of organizational change in DT. To specifically account for the relevant levels of analysis, we draw from existing conceptualizations of levels of analysis (Iden & Bygstad, 2024; Kozlowski & Klein, 2000; Mirbabaie & Marx, 2024) differentiating the micro-, meso-, and macro-level (Cowen et al., 2022; Kouamé & Langley, 2018). These three levels of analysis form the basis of our multi-level analysis framework, which serves as a means to for integrating the two perspectives (i.e., *what* and *how*) and structuring organizational change in DT within and across levels of analysis. Subchapter 3.2.3 details the different levels of analysis and their properties.

Starting with the coding terminology of Gioia et al. (2013), we used an open coding procedure to discover initial concepts within data. In other words, we screened the gained data from DT literature for any mention of activities, changes, or actions that organizations undergo as part of their DT. To do so, one member of the research team conducted in vivo coding and highlighted all original text excerpts that may be relevant to our context, extracted these excerpts, and used them to formulate change-oriented statements on DT. The initial coding

table was double-checked by all other team members individually and discussed within the whole team, yielding 95 DT initiatives. In the second step, all authors compared the DT initiatives discovered during the first step within group sessions, identified similarities and differences between them, and observed that these DT initiatives further synthesize into a set of 23 DT patterns that describe organizational change in a specific area of an organization (Gioia et al., 2013). The process involved shifting back and forth between the DT initiatives and the emerging DT patterns to constantly revise the emerging change constructs in light of new findings and to align divergent representations until theoretical saturation was reached (Glaser & Strauss, 1967). In the final analysis step, we recognized that the emergent DT patterns distill further into overarching DT themes that describe organization-wide changes across multiple areas of an organization. Overall, the emerging DT initiatives, DT patterns, and DT themes describe organizational change in DT at different levels of abstraction. The results of our final data structure as well as the different levels of abstraction confirm that organizational change in DT is a multi-level phenomenon that must be understood at different levels of analysis.

Overall, the final data structure of 95 DT initiatives, 23 DT patterns, and seven DT themes provides a static overview of *what* changes in the context of DT within and across different levels of analysis. Appendix B.3 depicts all DT initiatives, DT patterns, and DT themes with exemplary references, evidencing the scientific rigor of our coding (Gioia et al., 2013).

Theorizing on How Change Unfolds

To set our static picture of a dynamic phenomenon in motion, we continued theorizing *how* change unfolds in DT within and across levels of analysis. Increasing the level of abstraction within the static data structure is a fundamental step to balance deep insights from empirical data with an adequately broad perspective needed for theorizing (Gioia et al., 2013). Our theorizing followed a process of individual assessments and joint discussions within the author team. Although we sought to thoroughly ground our findings, theory building is inherently imaginative (Leidner, 2018; Rivard, 2014). Its results can therefore not be fully traced by simply reprocessing the methods used (Markus & Rowe, 2021), but are the consequence of the author's intimate knowledge of the data (Gioia et al., 2013).

The author team first intensively analyzed and discussed the change constructs found at the different levels of analysis to develop first ideas about *how* organizational change unfolds from an intra- and inter-level perspective. These first ideas were informed by existing literature on

the nature of organizational change (e.g., Hanelt, Bohnsack, et al., 2021; Iden & Bygstad, 2024; Kaganer et al., 2023) and shaped by the author's personal experiences derived from their participation in industry projects with organizations undergoing DT (Fisher et al., 2021). We debated these ideas within the author team and supported them with empirical data and examples from literature. Starting at the lowest level (i.e., the micro-level) of our multi-level analysis framework, we found that organizational change brought about by DT initiatives can vary in frequency of change and radicality of change. Frequency of change refers to how often a DT initiative triggers change within the organization (high vs. low frequency) (K. Lee et al., 2017). It can be measured over a period of time (e.g., daily, weekly, monthly), where daily or weekly change indicates a high frequency, while yearly changes would be classified as low frequency. Radicality of change refers to the degree of change that a DT initiative brings about (high vs. low radicality). Drawing from existing knowledge about organizational change, DT initiatives with high frequency and low radicality follow a more continuous manner of change, whereas DT initiatives with low frequency and high radicality follow a more episodic manner of change (Lyytinen & Newman, 2008).

We classified each DT initiative in terms of frequency and radicality to assign them either to continuous or episodic change. This step is essential as change from the micro-level aggregates upwards. To ensure the accuracy of these classifications, two co-authors independently classified each DT initiative. The initial assignment yielded an intercoder reliability of 93.40%. The resulting combinations of frequency and radicality were then discussed with the whole author team. It must be said that DT initiatives of high frequency and high radicality seem rather of a theoretical nature, while those with a low frequency and low radicality are likely to be too irrelevant to detect. Moving back and forth between the DT initiatives and the different types of change, the classification of all DT initiatives as either continuous or episodic was finalized.

As written in Subchapter 3.2.1, multi-level theorizing allows to understand how smaller changes at the individual level influence profound changes at the organizational level (Kouamé & Langley, 2018). Therefore, the author team continued to discuss organizational change at the higher levels of analysis (meso- and macro-level) and developed a convergent set of assumptions about *how* organizational change unfolds in DT across levels. Depending on the type of change in DT initiatives at the micro-level, change at all levels above can unfold in different ways. We compared the configurations of DT patterns at the meso-level, while iteratively refining our assumptions. DT patterns can consist exclusively of episodic DT initiatives, exclusively of continuous DT initiatives, or of a mixture of episodic and continuous

DT initiatives (what we call hybrid DT patterns). Within the next step of our analysis, we evaluated change at the macro-level, where we found different combinations of DT patterns. At the macro-level DT themes consist of multiple (episodic, continuous, or hybrid) DT patterns. Therefore, the nature of change in the respective DT patterns informs how change unfolds in the macro-level DT theme. The synthesis of all discussions, empirical data, and assumptions was then used to build the proposed multi-level perspective on organizational change in DT.

3.2.3 Results

In the following, we present our results outlining a multi-level understanding of the nature of organizational change in the context of DT. Specifically, this subchapter sheds light on *what* changes in DT and *how* the associated change unfolds. We generated these insights by means of a multi-level analysis framework, which emerged during the coding procedure complemented with existing research on multi-level phenomena including definitions of levels and change constructs. We show *what* changes in the context of DT at each level of analysis (intra-level perspective) and across levels of analysis (inter-level perspective). We then use these findings to theorize *how* change unfolds at each level (intra-level perspective) and across levels (inter-level perspective).

Multi-level Analysis Framework of Change in Digital Transformation

Throughout the analysis, we assessed the extensive body of DT research from a multi-level perspective (e.g., Carroll, Conboy, et al., 2023; Gregory et al., 2018; Hanelt, Bohnsack, et al., 2021; Vial, 2019). Similar to other multi-level research, the emerging change constructs (i.e., DT initiatives, DT patterns, and DT themes) differ in their level of analysis. Complementing existing conceptualizations of micro-, meso-, and macro-level change, the resulting change constructs can be mapped onto distinct levels of analysis. Table 7 provides an overview of the different levels of analysis and the change constructs, including their scope, definition, and an example. The micro-level centers around individuals or small teams working on the same project. In contrast, the meso- and macro-level include change in larger areas of the organization. The structure of the organizational areas was inspired by the organizational layers of the work systems theory (Alter, 2002, 2013).

At the micro-level, organizational change concerns individuals (i.e., employees) or teams (i.e., project teams working on the same initiative) and the concrete initiatives they undertake as part of their employment to drive DT (Findikoglu & Watson-Manheim, 2016; Iden & Bygstad,

2024; Mirbabaie & Marx, 2024). Organizational change at the micro-level is reflected in *DT initiatives*, as seen throughout the coding procedure. DT initiatives are concrete changes embedded in employees' work routines and/or projects. An example of a DT initiative is the provision of customized self-learning opportunities that are easily integrable in the daily routine (e.g., mobile learning) (Lauterbach et al., 2020).

Level	Scope	Change Construct	Definition	Example
Macro	Organization	DT Theme	Organization-wide changes embedded in and across multiple areas of an organization	Unfolding of employee engagement
Meso	Department	DT Pattern	Collective changes embedded in a specific area of an organization	Transforming from a focus on promoting employees' domain expertise to developing learning opportunities that promote digital literacy
Micro	Individual/ Team	DT Initiative	Concrete changes embedded in employees' work routines and/or projects	Provide customized self-learning opportunities that are easily integrable in the daily routine

Table 7: Overview of Digital Transformation Change Constructs and Levels of Analysis

At the meso-level, organizational change takes place in entire departments within an organization and is brought about by a series of DT initiatives (Findikoglu & Watson-Manheim, 2016). The bundling of DT initiatives results in a *DT pattern*. A DT pattern describes collective changes that lead to larger reorientations of a specific area of an organization (e.g., people, strategy, culture). Following the notion of patterns as applied by Ortiz de Guinea and Webster (2013) and Meyer et al. (1993) we understand patterns in general as the configuration of similar, but distinct elements to conceptualize them jointly at a higher level of abstraction to reduce complexity. An example of a DT pattern in the people area of an organization is the transformation from a focus on promoting employees' domain expertise to additionally developing learning opportunities that promote digital literacy.

At the macro-level, the changes affect the entire organization (Findikoglu & Watson-Manheim, 2016; Jensen et al., 2009). These organization-wide changes are referred to as *DT themes*. DT themes involve broader strategic changes and are central building blocks of DT that span multiple areas of an organization. An example of a DT theme is the unfolding of employee engagement, which encompasses areas such as people and culture. DT themes are fundamental

changes of DT, as organizations aiming to master DT need to consider all areas of an organization and their interdependencies over time.

In the last paragraphs, we presented the change constructs (i.e., DT initiatives, DT patterns, DT themes) along the different levels of analysis (i.e., micro-, meso-, macro-level). Note that all three change constructs refer to DT in the sense that they have been observed and communicated as part of real-life DT in literature. It does not mean, however, that all specific examples can only exclusively be used for DT. For example, a DT pattern such as *transforming from a change-reluctant culture to an entrepreneurial culture fully embracing change as an opportunity* could also be an important building block of cultural transformations. The understanding of different levels of analysis in DT results from integrating existing conceptualizations of levels in other contexts with the specific change constructs in DT. Figure 7 provides an overview of the multi-level analysis framework in its most generic version before we show *what* changes in the context of DT at each level of analysis (intra-level perspective) and across levels of analysis (inter-level perspective) and illustrate *how* organizational change unfolds from an intra- and inter-level perspective.

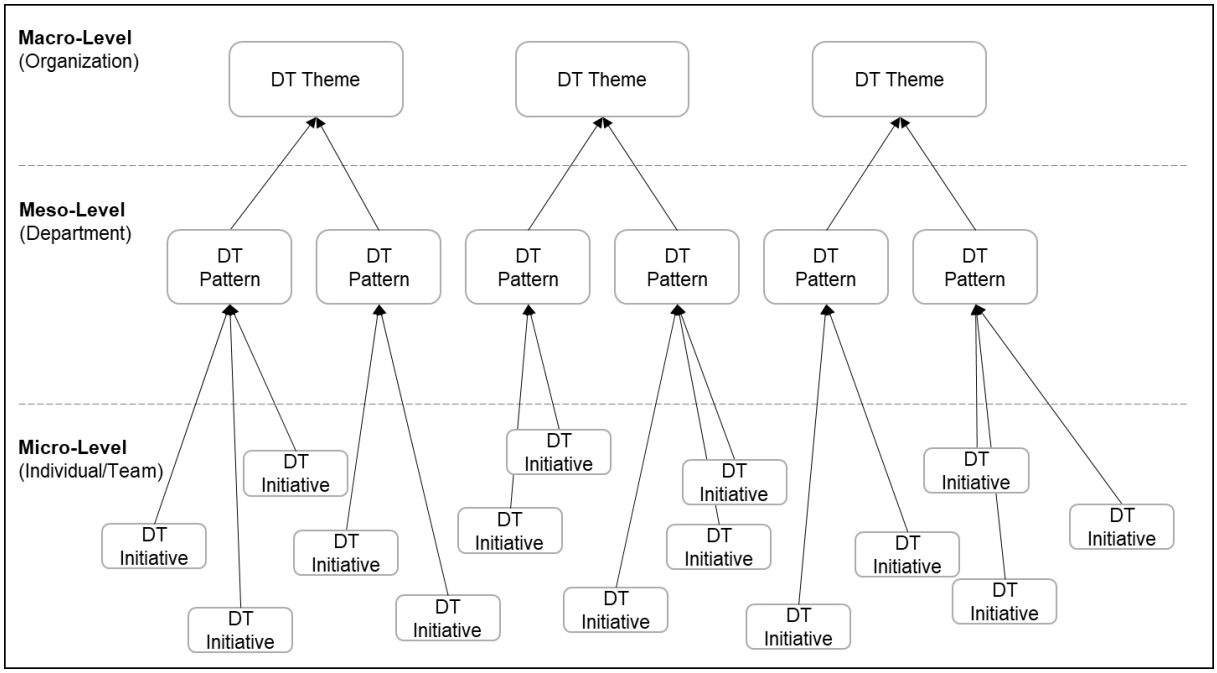


Figure 7: Multi-level Analysis Framework for Change in Digital Transformation

What Changes in the Context of Digital Transformation?

We first assess *what* changes in the context of DT at the micro-, meso-, and macro-level in the form of DT initiatives, DT patterns, and DT themes. Based on a structured literature review,

we found 95 DT initiatives, 23 DT patterns, and seven DT themes, each describing organizational changes in the context of DT at one level of analysis. In the following, we present these changes at the micro-, meso-, and macro-level (intra-level perspective) and their relationships (inter-level perspective). Figure 8 shows our multi-level analysis framework including DT themes, DT patterns, and exemplary DT initiatives. The DT themes follow no specific order from left to right. For each DT theme, we briefly present the underlying DT patterns and provide a more detailed description of specific DT initiatives for one exemplary DT pattern per theme. A list of all 95 DT initiatives can be found in Appendix B.3.

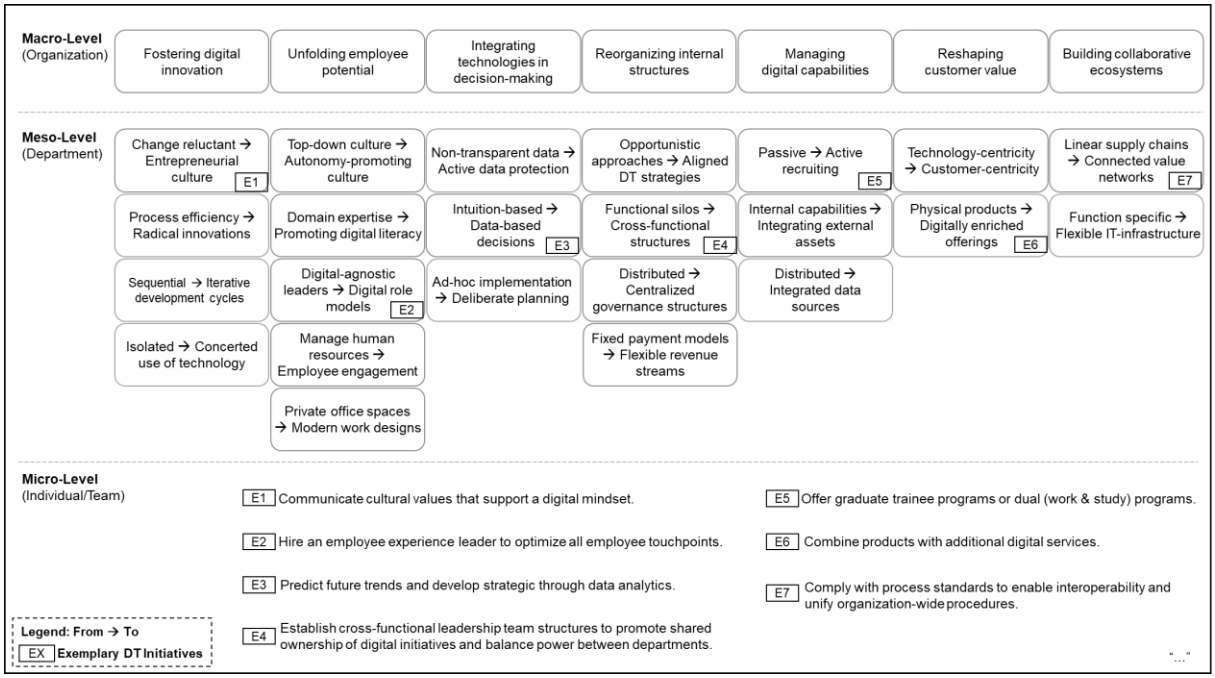


Figure 8: Overview of What Changes in the Context of Digital Transformations

The DT theme of *fostering digital innovation* at the macro-level focuses on improving digital innovation capabilities through different DT patterns. During our data analysis, we found that fostering digital innovation can be achieved at the meso-level by transforming (1) from a change-reluctant culture to an entrepreneurial culture fully embracing change as an opportunity, (2) from a predominant focus on efficiency-oriented process improvements to including radical innovations, (3) from sequential to iterative product and service development processes through rapid prototyping and experimentation, and (4) from isolated to concerted use of digital technologies, which enables continuous adaptation and re-combination. This DT theme highlights how digital innovation in general, but also digital innovation for sustainability in particular, are embedded within overall organizational DTs.

The DT pattern "transforming from a change-reluctant culture to an entrepreneurial culture fully embracing change as an opportunity" includes concrete DT initiatives at the micro-level, such as communicating cultural values that support a digital mindset throughout the organization (e.g., through a cultural ambassador program) (e.g., Barthel & Hess, 2020) or encouraging a trial-and-error culture to foster experimentation (e.g., J. Magnusson et al., 2020). Managing incentives for a hands-on start-up mentality and outside-the-box thinking are further critical DT initiatives to open new avenues for innovation (e.g., Agarwal et al., 2010). In addition to cultural values, another DT initiative focuses on communicating the value of data throughout the organization to drive a data-driven culture (e.g., Barthel & Hess, 2020).

The DT theme of *unfolding employee potential* refers to changes within an organization that empower employees to drive DT in a self-determined way. What makes this DT theme particularly important is that the success of DT depends on the employees who participate in it and their skills (Chanias et al., 2019), the leaders who set an example, and the work environment that sets the stage. Our findings reveal that unfolding employee potential can be achieved at the meso-level by transforming (1) from a top-down culture to a culture that empowers individuals to become active members of DT, (2) from a focus on promoting employees' domain expertise to developing learning opportunities that promote digital literacy, (3) from digital-agnostic leadership roles and responsibilities to digital role models, (4) from a narrow focus on the management of human resources to a broader focus that includes the promotion of active employee engagement, and (5) from private office spaces to new work environments that modernize work design.

"Transforming from a top-down culture to a culture that empowers individuals to become active members of DT", i.e. DT pattern 1), requires concrete DT initiatives at the micro-level, such as the redesign to autonomous and flexible decision-making processes to increase decision speed (e.g., Baiyere et al., 2020) or increasing autonomy in team selection and management (e.g., Barthel & Hess, 2020). In addition, the involvement of employees in the DT through bottom-up approaches is part of this DT pattern. These efforts require the provision of resources (e.g., financial budgets, infrastructure, time) to employees (Karimi & Walter, 2015; Tanniru et al., 2018).

The DT theme of *integrating technologies in decision-making* involves the integration of data and related data protection measures as well as the targeted selection of a technology portfolio for the conscious and sustainable design of DT in organizations. The DT theme at the macro-

level can be achieved at the meso-level by transforming (1) from non-transparent data processing to active data protection through privacy-by-design, (2) from intuition-based to data-based decision-making, and (3) from ad-hoc implementation of digital technologies to deliberate planning of digital technology adoption.

The change of DT pattern (1) "from non-transparent data processing to active data protection through privacy-by-design" takes place at meso-level through a combination of DT initiatives at the micro-level. These DT initiatives include performing data quality management for consistency, relevance, and reliability of data (e.g., Davenport & Redman, 2020), monitoring data privacy and security in the collection, transfer, and use of personal data (e.g., J. Y. H. Lee et al., 2020), and performing data governance (i.e., policies, procedures, standards) to ensure data integrity across initiatives (e.g., Ives et al., 2016).

The DT theme *reorganizing internal structures* refers to the dismantling of existing structures that separate the actions of individual business units to promote knowledge exchange and collaboration through new organizational structures (A. Singh & Hess, 2017). Reorganizing internal structures requires several changes at the meso-level. Departments need to transform (1) from opportunistic approaches to DT to a clearly defined and aligned digital transformation strategy, (2) from functional silos into cross-functional collaboration and team-based structures, (3) from distributed to centralized and aligned DT governance structures, and (4) from fixed payment and ownership models to flexible revenue streams facilitated by digital service innovations and the sharing economy.

The DT pattern (3) centers around "aligning DT governance structures". It includes concrete DT initiatives at the micro-level, such as establishing a digital advisory board to support management with internal and external experts (Chanias et al., 2019), establishing dedicated steering and executive committees that bundle DT efforts and make key decisions about investments and resource allocations (Kappelman et al., 2019), or establishing a central digital business unit (e.g., digital innovation hub, digital factory) for innovation (Hinings et al., 2018).

The DT theme of *managing digital capabilities* groups together the various changes required for an organization to build and sustain core DT competencies and capabilities. Our findings reveal that managing digital capabilities can be achieved at the meso-level by transforming (1) from passive to active recruiting that focuses on digital talent and expertise, (2) from a focus on internal capabilities to additionally embracing external resources, and (3) from distributed

internal data sources to integrating a variety of data sources within and across organizational boundaries.

Possible DT initiatives within the DT pattern (1) "transforming from passive to active recruiting" include establishing a center of excellence for recruiting external digital talent (e.g., T. Fischer et al., 2020), conducting employer branding campaigns (e.g., Haffke et al., 2017), collaborating with universities or research institutions to connect with digital natives at an early stage (e.g., Hess et al., 2016), and offering graduate trainee or dual (work & study) programs (e.g., Mädche, 2016).

The DT theme of *reshaping customer value* is central to DT, as organizations need to align their value proposition with customer desires and expectations to remain competitive in the digital economy. In the digital era, customers are no longer mere customers but also business partners (Warner & Wäger, 2019). To accommodate this change, departments at the meso-level must transform (1) from product- and technology-focused to business- and customer-focused value propositions and (2) from physical to digitally enriched offerings with a focus on digital service innovations.

The transformation of DT pattern (1) "from product- and technology-focused to business- and customer-focused value propositions" is supported at the micro-level by the development of a customer-facing digital service platform and the digitalization of all touchpoints (including sales and distribution channels) along the customer journey (e.g., Dery et al.; Sebastian et al., 2017). Further, applying customer analysis tools (e.g., customer journeys, personas) (e.g., Gill & VanBoskirk, 2016) and integrating customer-centric innovation methods (e.g., design thinking) helps to find solutions that are convincing from a user's point of view (e.g., Chanias et al., 2019).

Lastly, the DT theme of *building collaborative ecosystems* recognizes the increasing importance of external partnerships, driven by the loosening of organizational boundaries. Not only does this loosening lead to changes in the ecosystem. It also necessitates an adapted set-up of infrastructures and technologies. To build collaborative ecosystems, departments at the meso-level are transforming (1) from linear supply chains to highly connected value networks and (2) from a function-specific organizational IT infrastructure to a flexible and modular IT infrastructure with high interoperability.

The DT pattern (1) to "transform from linear supply chains to highly connected value networks" builds on DT initiatives at the micro-level such as collaborating in digital ecosystems to seek

strategic alliances (e.g., Leinwand & Mani, 2021) and driving new forms of innovation, such as open innovation (e.g., Vial, 2019). Another DT initiative is to involve users and customers in the innovation process (e.g., T. Fischer et al., 2020). To increase stakeholders' willingness to connect within digital ecosystems, incentives are created at the micro-level (e.g., Teubner & Stockhinger, 2020). Other DT initiatives include investing in multi-sided business models (e.g., Bharadwaj et al., 2013) and experimenting with sharing and collaborative consumption business models (e.g., Gurbaxani & Dunkle, 2019).

How does Organizational Change Unfold in the Context of Digital Transformation?

After intensively analyzing existing literature concerning *what* changes in the context of DT (i.e., DT initiatives, DT patterns, DT themes) within each and across levels of analysis, the question arises as to *how* change unfolds in the context of DT. Therefore, we first assess the different change constructs individually regarding their nature of change by building on our data. Second, a closer look at the interaction between levels of analysis is in focus.

Analyzing the different levels of analysis in DT and their change constructs, we find that organizational change in DT starts at the smallest level, namely the micro-level and the respective individuals and/or teams. Generally, multi-level theorizing forms on the assumption that macro-level phenomena (in this case DT) form based on micro-level activities and processes (Kozlowski & Klein, 2000). For DT in particular, the micro-level is the foundation as neither departments (meso-level) nor organizations (macro-level) can make decisions or perform activities themselves (Iden & Bygstad, 2024; Kaganer et al., 2023). Only the human actors (micro-level) have the ability for such actions, ultimately triggering change (Kouamé & Langley, 2018; Poláková-Kersten et al., 2023). The results of our analysis show that change at the higher levels arises from the aggregation of change from the levels below. For example, the macro-level DT theme "unfolding employee engagement" cannot be executed by an organization at the macro-level. Rather, individuals and/or teams need to conduct many smaller initiatives (e.g., providing experimental learning opportunities or designing modern and flexible office concepts) to reach it. Consequently, change at the meso-level is created by an aggregation of micro-level DT initiatives, while change at the macro-level emerges by an aggregation of meso-level DT patterns. We thus argue that the nature of organizational change within the lower levels of analysis defines the nature of organizational change in DT at the higher levels (Kouamé & Langley, 2018; Kozlowski & Klein, 2000). To explicate how exactly change unfolds in DT, it is first necessary to understand change processes at the micro-level.

During data analysis, we observed that the smaller organizational changes brought about by DT initiatives at the micro-level can vary in frequency and radicality (K. Lee et al., 2017). Consider the DT theme of "unfolding employee engagement", which at the lowest level includes concrete DT initiatives, such as providing experimental learning opportunities (e.g., Liang Li et al., 2018) or designing modern and flexible office concepts (e.g., Jensen, 2018). The design of modern and flexible office concepts is certainly a highly infrequent change within the organization, as there is neither the need nor the resource base for individuals to execute such a project on a daily, weekly, or even monthly basis. Therefore, the change stemming from such a redesign project only happens rarely. At the individual level, this change includes, for example, a shift with respect to the specific working location or the usage of communication facilities. However, when executed, this type of project brings about significant amounts of change for the organization. This is due to a) the fact that it affects many people in the organization and b) it requires breaking down fundamental existing organizational structures to pave the way for a supportive and dynamic workplace culture. On the other hand, change is highly frequent within DT initiatives, such as providing experimental learning opportunities. With training and education, employees continuously change and improve their knowledge base with every new training that is being offered. Employees do not learn only once every year, but they are at least weekly being confronted with opportunities to learn something. However, these DT initiatives only inflict small changes at a time, for example, one employee knowing about one additional digital technology after learning about it. Unlike the DT initiative to design modern and flexible office concepts, these DT initiatives do not result in immediate radical change. Rather, the sum of such initiatives leads to more fundamental changes over time.

On a more general level, the empirical observations from our data regarding the frequency and radicality of change can be mapped to the theoretical foundations of change types in DT. DT initiatives with low frequency but high radicality of change fit the theoretical understanding of episodic change (Lyytinen & Newman, 2008). In contrast, high frequency with low radicality of change implies a continuous change nature at the micro-level (Lyytinen & Newman, 2008). As a consequence, all 95 DT initiatives derived from the literature were classified as either continuous (n=56) or episodic (n=39), depending on how change unfolds in the respective DT initiative. Figure 9 below illustrates how the spectrum of frequency and radicality serves as the basis for the classification of DT initiatives. As seen in Figure 9, there are DT initiatives that are very clearly episodic or continuous, and there are edge cases closer to the dotted line.

However, we did not find any DT initiatives that are both – clearly episodic for some time and then shifting to being clearly continuous. Therefore, we distinctly assigned each DT pattern the type of change it belongs to more closely. Note that the two grey triangles exist in the theoretical diagram but are not relevant for this dissertation. The lower left triangle depicts initiatives with low frequency and low radicality, which have no prioritization. In contrast, the upper right triangle (high frequency, high radicality) would be highly important, but we have not found any DT initiative highly frequently conducted, always triggering substantial, radical change. In Appendix B.3, the classification of each DT initiative as either continuous or episodic is given.

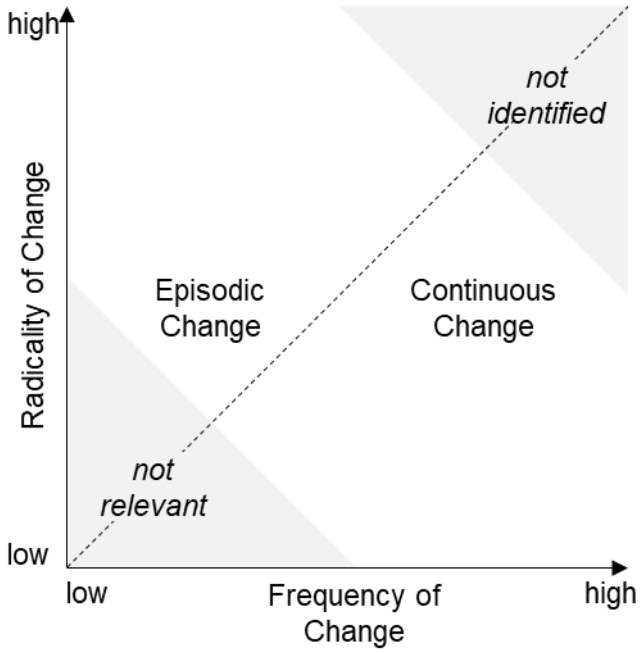


Figure 9: Classification Framework for Digital Transformation Initiatives

Depending on the type of change in DT initiatives at the micro-level, change at all levels above can unfold in different ways. In the analysis, DT patterns (i.e. the meso-level) emerged from the aggregation of similar DT initiatives (i.e., micro-level). Therein, the DT patterns constitute an aggregation of a set of episodic and/ or continuous DT initiatives. In the set of 23 DT patterns, three distinct cases emerged: (1) DT patterns that consist only of episodic DT initiatives (four DT patterns in the sample, e.g., *transforming from private office spaces to new work environments that modernize work design*), (2) DT patterns that consist only of continuous DT initiatives (eight DT patterns in the sample, e.g., *transforming from intuition-based to data-based decision-making*), and (3) DT patterns that consist of a mixture of episodic and continuous DT initiatives (so-called hybrid DT patterns; 11 DT patterns in the sample, e.g., *transforming from a focus on internal capabilities to additionally embracing external*

resources) (Figures 10-12). We proceed to illustrate how change aggregates from the micro- to the meso-level for all three cases.

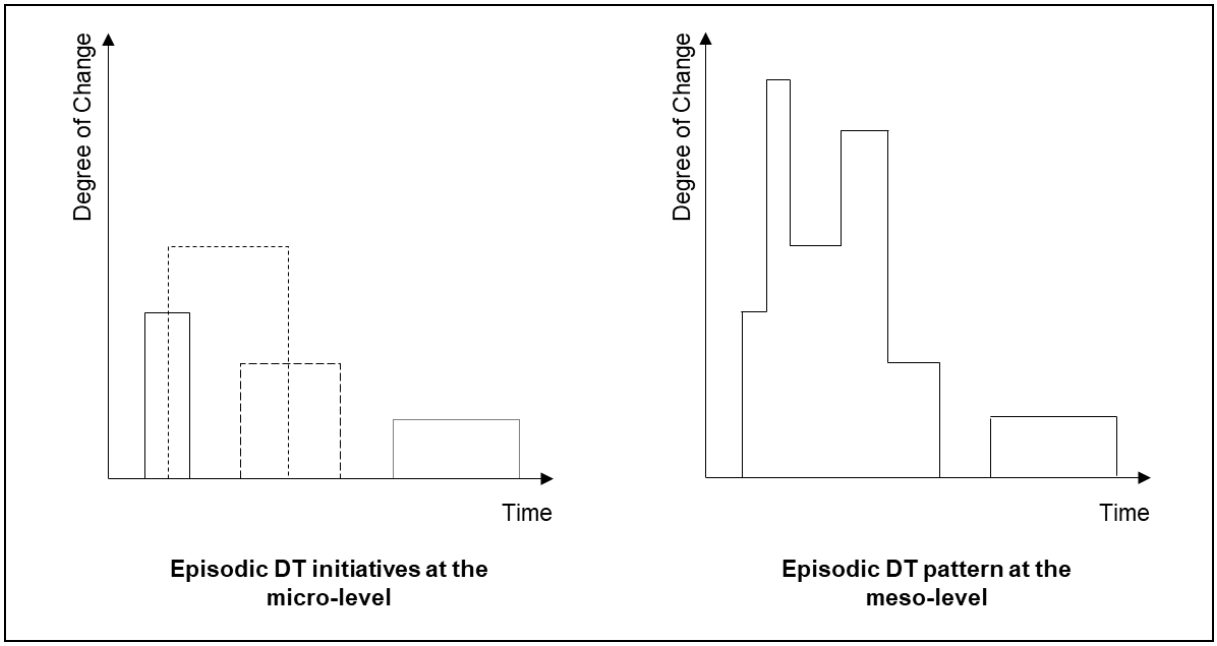


Figure 10: Aggregation to Episodic Digital Transformation Patterns

In case 1), DT patterns consist only of episodic DT initiatives. This type exists, for example, when organizations set up a project roadmap for larger, resource-intensive DT projects. The establishment of new digital work is one such example, where organizations simultaneously redesign desk spaces, develop and implement concepts for creative collaboration, and introduce new digital infrastructure for flexible working – all of which are larger, episodic DT initiatives (Brünker et al., 2023; Jensen, 2018). Figure 10 illustrates the implicated level of change at different points in time at the micro-level (left side), as well as their aggregation at the meso-level (right side). Depending on the set of DT initiatives, the episodes of change (rectangles in Figure 10) sometimes occur at the same point in time. This is the case, for example, when many DT initiatives are started as explicit DT projects in parallel and take effect at the same moment. In other cases, DT initiatives are conducted with an offset to each other (e.g., to adhere to budget restraints). Depending on the timing, the aggregation of episodic DT initiatives can either lead to a balancing effect (i.e., little time with no change as DT initiatives unfold their effect at different times) or a cumulation of change (DT initiatives trigger change at the same time).

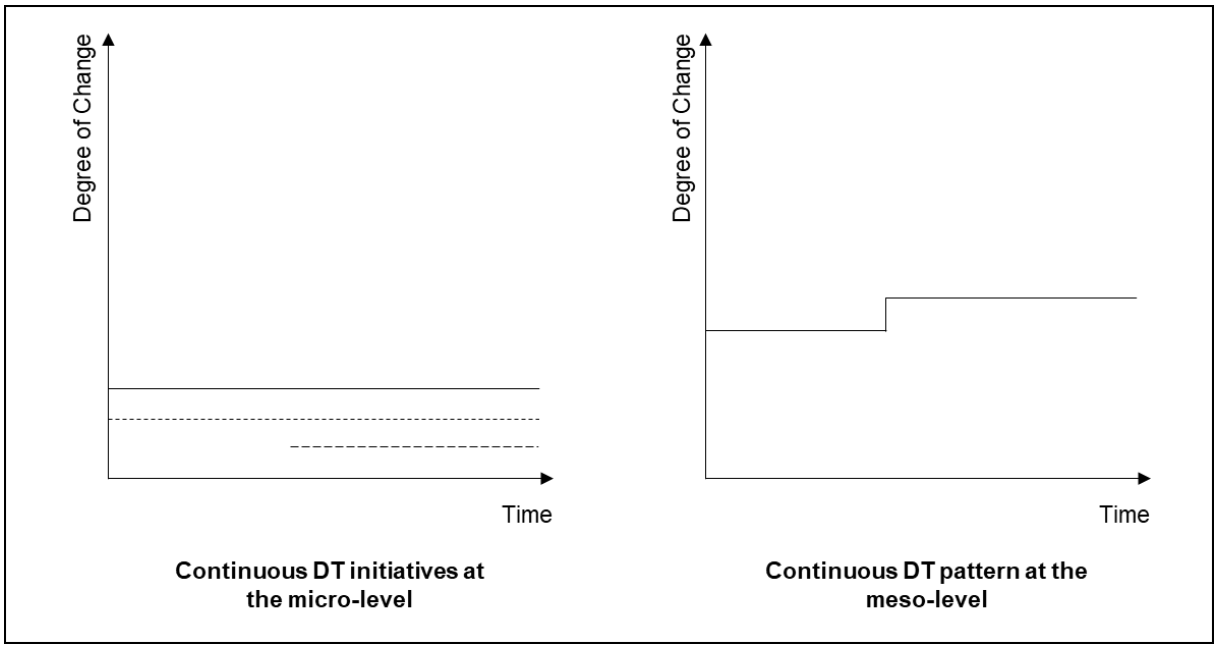


Figure 11: Aggregation to Continuous Digital Transformation Patterns

In case 2), a DT pattern consists only of continuous DT initiatives (Figure 11). In DT, such patterns often concern social topics around culture, learning, or mindsets as they cannot simply be changed overnight but require continuous small changes. Continuous DT initiatives, once started, are independent of certain time slots as they constantly trigger at least a small amount of change. In the data, this was observable, for example, in the case of bundling DT initiatives to increasingly and continuously engage employees in topics related to DT (Dery et al., 2017; Dremel et al., 2017). Organizations do not change fundamentally if one employee contributes a DT-related idea once. Instead, the continuous involvement of many employees can lead to significant advances in the DT journey. In contrast to case 1, there is no balancing of times with high and low change levels. Rather, the DT pattern is a summation of many streams of continuous change. Therefore, DT patterns composed of only continuous DT initiatives are still continuous in nature – simply at a higher radicality of change than at the micro-level.

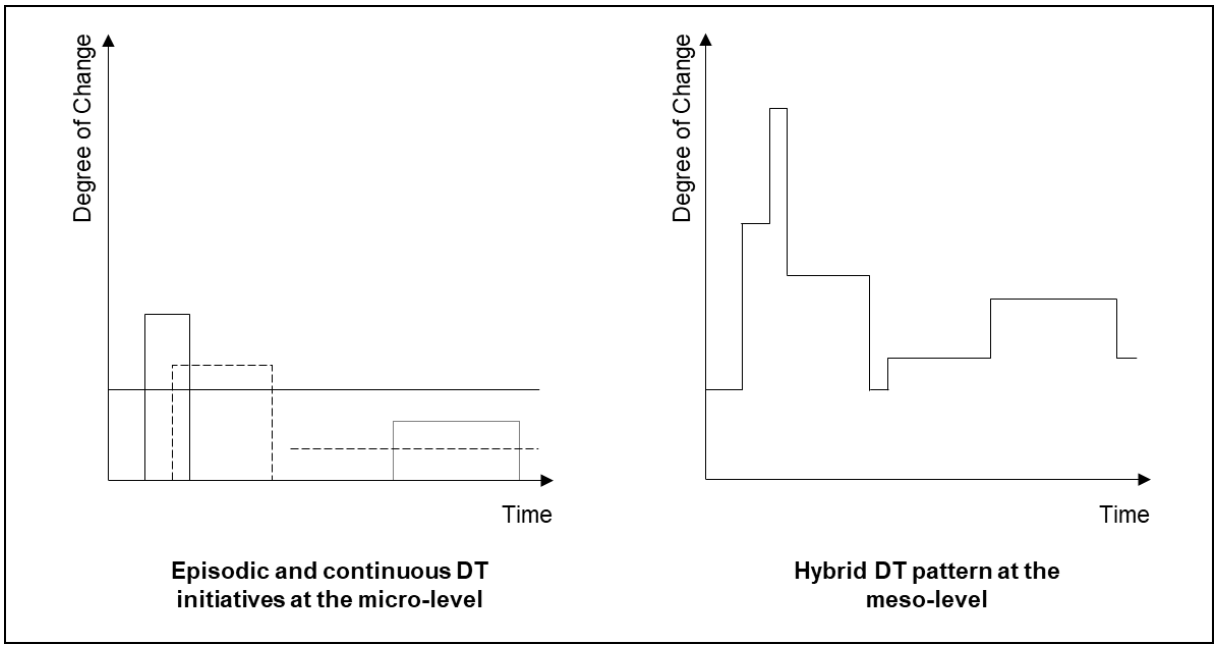


Figure 12: Aggregation to Hybrid Digital Transformation Patterns

In case 3), a DT pattern consists of both episodic and continuous DT initiatives and is thus of hybrid form (Figure 12). Here, DT initiatives with high radicality of change and low frequency occur in parallel with DT initiatives with low radicality of change and high frequency. Usually, this indicates that for specific hybrid DT patterns, organizations conduct a few larger episodic projects in addition to smaller continuous changes in daily routines. In this case, the aggregation of the continuous DT initiatives sets the baseline for the minimal amount of change within the hybrid DT pattern. In addition, once an episodic DT initiative takes place, the amount of change increases accordingly for the time of the episode. As in case 1, the aggregation of many episodes with different starting times can lead to a balancing of high and low change-level periods. This is the case, for example, when the strategic time plan for a DT schedules one larger, episodic DT initiative every month.

In sum, the aggregation of the DT initiatives observed in literature leads to the formation of episodic, continuous, and hybrid DT patterns at the meso-level. From a practical standpoint, the existence of purely episodic DT patterns (long periods of stability, short periods of radical change) is rare, as it would require that all underlying DT initiatives start at the same point in time, last the same amount of time, and implicate the same level of change. Rather, an evolution towards hybrid and continuous change can be observed at the meso-level.

Shifting towards the next level of aggregation, the question of how change unfolds in the macro-level arises. As before, the results show that macro-level DT themes consist of multiple

(episodic, continuous, or hybrid) DT patterns, in turn consisting of DT initiatives. Therefore, the nature of change in the respective DT patterns informs how change unfolds in the macro-level DT theme. In our analysis, all seven DT themes at the macro-level consist of a mixture of different types of DT patterns. Therefore, all the existing DT themes identified in this analysis follow a hybrid nature of change. This, again, means that change in the respective theme has a continuous minimal stream of change, complemented by episodic periods which (depending on the case) are more or less balanced. From a theoretical standpoint, there could exist three cases at the macro-level, which resemble the dynamics seen in the patterns above. As a first edge-case, a DT theme can consist of only episodic DT patterns, which would lead to a purely episodic DT theme if all the underlying DT initiatives were timed synchronously (cf., Figure 10). In a second edge-case, a DT theme can consist of only continuous DT patterns, which would lead to a purely continuous DT theme (cf., Figure 11). In the third case, a DT theme consists of a combination of episodic, continuous, and already hybrid DT patterns. In this case, the DT theme would resemble Figure 12, with a certain amount of continuous change that increases/decreases depending on the episodic components of its DT patterns. However, as stated, in the analyzed literature sample, the macro-level DT themes appear to be always hybrid.

Figure 13 illustrates the aggregation of change across levels for the DT theme on digital innovation and the corresponding DT patterns and DT initiatives. The results show how at the micro-level, episodic and continuous DT initiatives coexist. Throughout the levels, the overarching change constructs move towards a more continuous nature.

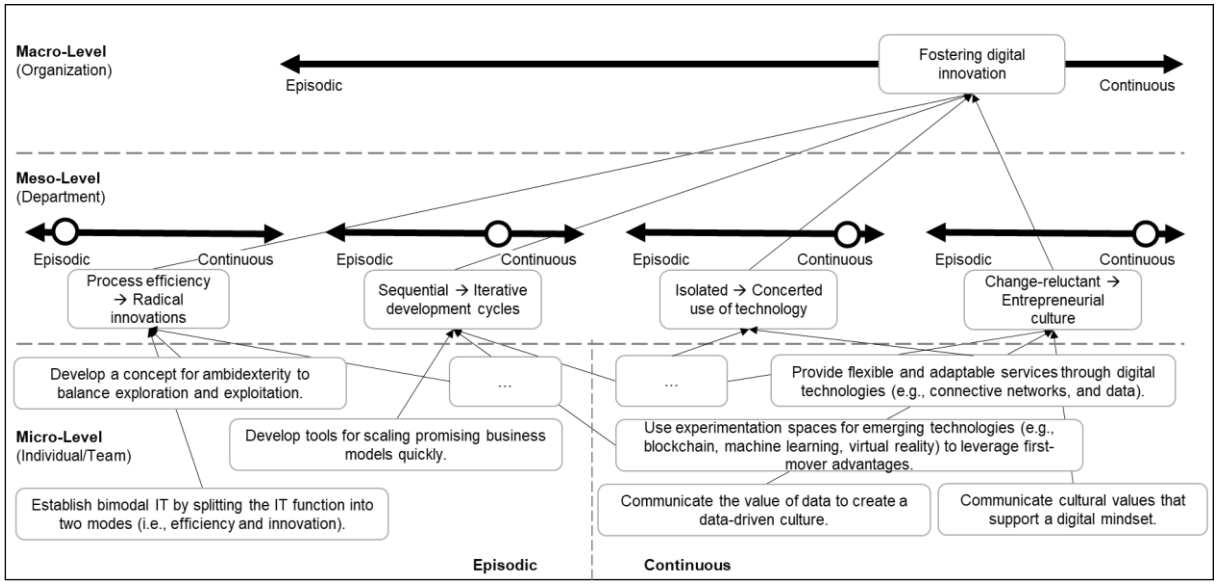


Figure 13: Exemplary Change Aggregation for the Digital Transformation Theme "Fostering Digital Innovation"

On a general level, our results demonstrate that a clear assignment between episodic and continuous DT initiatives is possible at the micro-level. While at the meso-level, the DT patterns in our data trend toward hybrid DT patterns (11/23), we also see exclusively episodic DT patterns (4/23) and exclusively continuous DT patterns (8/23). At the macro-level, the trend toward hybrid DT themes intensifies due to the increasing overlap of different types of change, what is clearly visible in our data with only hybrid DT patterns (7/7).

3.2.4 Discussion

Contribution

DT is top of the agenda for many researchers and practitioners. Nevertheless, DT success rates remain low (Wade & Shan, 2020). One barrier to successful DT that has been discussed in research is a missing awareness of *what* changes in DT and *how* the associated change affects the organization (Soluk & Kammerlander, 2021; Taheri et al., 2022; Tijan et al., 2021). To reduce this barrier and increase DT success rates, organizations have to understand *what* changes during DT and *how* organizational change unfolds at different levels of analysis. Our analysis contributes to this challenge. The overarching contribution of this subchapter presents a multi-level perspective on organizational change in DT. On a detailed level, there is a threefold contribution to that effort by, (1) developing a multi-level analysis framework, (2) providing an overview of the specific organizational changes that constitute DT (i.e., the *what*), and (3), demonstrating *how* organizational change unfolds within and across the different levels.

First, the analysis shows that organizational change in the context of DT is a complex phenomenon that is difficult to understand from a single-level perspective (Iden & Bygstad, 2024; Oberländer et al., 2024). Therefore, our first contribution is a multi-level analysis framework that differentiates between the micro-, meso-, and macro-level of analysis. Considering the specifics of each level of analysis contributes to a better understanding of the underlying change constructs. The framework helps to structure *what* changes occur in the context of DT at each level of analysis (intra-level perspective) and across levels of analysis (inter-level perspective). A structured account of *what* changes at different levels of analysis supports drawing conclusions about *how* organizational change unfolds from an intra- and inter-level perspective. By integrating both perspectives (i.e., *what* changes and *how* change unfolds), the multi-level analysis framework serves as a means of explaining the complex phenomenon

of organizational change in the context of DT. Therein, the framework might also serve as a structuring tool to researchers investigating other questions around DT.

Second, based on a theorizing review, this subchapter contributes to a better understanding of *what* changes in the context of DT at the micro-, meso-, and macro-level in the form of DT initiatives, DT patterns, and DT themes. We coded the emerging DT initiatives, DT patterns, and DT themes with special attention to the level of analysis they refer to, which is not always explicitly stated in existing studies. Thereby, we analyze and synthesize valuable prior studies such as Hess et al. (2016), Vial (2019), or Chanias et al. (2019), to advance the current descriptive knowledge on organizational change in the context of DT. As a result, DT initiatives portray organizational changes within the projects and routines of individuals or teams, while DT patterns are aggregated organizational changes embedded in a specific area of an organization. Complementary, DT themes are organization-wide changes across different areas of an organization and are central building blocks of DT. For digital innovation for sustainability in particular, the DT theme on fostering digital innovation is central. The respective underlying DT patterns and DT initiatives hint to important digital innovation actions that organizations should include in their innovation endeavors.

Third, we build on the conceptualization of DT as a multi-level phenomenon and explore *how* organizational change unfolds within and between each level of analysis. We present evidence regarding the nature of organizational change for individuals/teams, departments, and the entire organization. The subchapter offers a clear view of the different types of change existing in DT (i.e., episodic, continuous, hybrid) as well as knowledge of *how* organizational change cascades throughout the levels. In particular, change at the micro-level can be either continuous or episodic, depending on the radicality and frequency of change with respect to the DT initiative. At higher levels, change increasingly becomes placed at a spectrum between episodic or continuous (i.e., hybrid) with a trend toward continuous change. This trend is due to the aggregation of different types of DT initiatives into higher-level change constructs and balancing effects between episodic DT initiatives. The types of change and their distribution differ substantially across levels. In that context, our results offer a clearer, more differentiated view of the nature of organizational change in the context of DT by moving away from single-level perspectives, to analyzing *how* change unfolds within and across different levels of analysis.

Theoretical Implications

The contributions have two main implications for the further study of organizational change in the context of DT in IS research: (1) they highlight a comprehensive, multi-level knowledge base for theorizing about organizational change in DT and (2) they bring together different, legitimate views on organizational change in DT and explain how they complement each other.

Firstly, in response to calls issued by, for example, Carroll, Hassan, et al. (2023), the DT initiatives, DT patterns, and DT themes discussed offer a comprehensive knowledge base of *what* changes in the context of DT within and across different levels of analysis. As noted by Vial (2019), DT triggers significant changes within the transforming organization. Wessel et al. (2021) describe these changes as redefined value propositions, which in turn lead to the emergence of new organizational identities. These profound changes occur at the overall organizational level (Wessel et al., 2021). However, value propositions and new organizational identities cannot be changed overnight. Rather, it takes a variety of different activities within the organization - each of which also triggers smaller organizational change - that subsequently lead to the formation of a new organizational identity. To understand *how* changes at each level interact and aggregate into larger changes, knowledge regarding *what* changes at different levels is required. To this end, we integrate different perspectives prevalent in current research. Within the sample, studies are focusing on the macro-level (e.g., Hanelt, Bohnsack, et al., 2021; Vial, 2019; Warner & Wäger, 2019), the meso-level (e.g., Chanias et al., 2019; Gregory et al., 2018; Piccoli et al., 2024), and the micro-level (e.g., Hinsen et al., 2019; Iden & Bygstad, 2024; Mirbabaie & Marx, 2024). In sum, we take account of the extensive work done in this field, synthesize its cumulative knowledge, and code it with respect to the different levels of analysis. For future theorizing, the change constructs identified within this subchapter serve as potential building blocks (Gregory & Henfridsson, 2021). For example, research could use the DT patterns as independent variables to quantitatively assess their impact on DT success (Gregor, 2006; Gregor & Hevner, 2013).

Secondly, regarding the nature of change in the context of DT, we emphasize DT as a multi-level phenomenon with different change constructs and types of change at the micro-, meso-, and macro-level. For research, these insights explain why studies differ in their assessment of organizational change in the context of DT. The prevailing view in the IS community is that DT is a source of continuous change (e.g., Chanias et al., 2019; Vial, 2019; Warner & Wäger, 2019). However, some studies view DT as an episodic change process (e.g., Drechsler et al.,

2020; Fuchs & Hess, 2018; Gregory et al., 2018; Piccoli et al., 2024) that includes radical and incremental changes. Others argue that DTs simultaneously comprise elements of both change types due to their uncertain boundaries (e.g., Hanelt, Bohnsack, et al., 2021). Our results have significant implications for this debate, which we expand on below.

Our analysis shows that the types of change and their distribution differ substantially across levels of analysis. For example, the micro-level comprises both episodic and continuous DT initiatives, while the macro-level (in our analysis) is only composed of hybrid DT themes. Part of current research's disparities in assessing DT change might stem from the fact that (1) studies consider different sets of DT initiatives/ DT patterns within the same level of analysis or (2) consider different levels of analysis. In respect to case 1, for instance, Piccoli et al. (2024) examine change in digital technology architecture at the meso-level. They come to the conclusion that DT is a *"one-time change of state"* (i.e., episodic) (Piccoli et al., 2024, p. 12). Similarly, Gregory et al. (2018) describe the transformation of IT governance (i.e., meso-level) as a radical change in organizational structures, also referring to an episodic manner of change. In contrast, Chanias et al. (2019, p. 12) focus on the implementation of a DT strategy (also meso-level) and define DT as a form of continuous change *"with no foreseeable end".* All three studies focus on the same level of analysis but with different sets of DT initiatives as the basis. As a result, the focus of change can shift towards episodic (e.g., infrastructure) or continuous (e.g., strategy) even within the same level.

Complementary to studies at the meso-level, Vial (2019) or Warner and Wäger (2019) assess DT at the macro-level. At this level of abstraction, change in DT is often defined as a form of continuous change. Here, the differences between levels of analysis (case 2 from the paragraph above) become relevant. The higher the level of analysis, the stronger the shift towards continuous and hybrid change due to the accumulation of change types and balancing effects between episodic change constructs. This explains why these studies might view organizational change in DT as continuous.

We provide reasoning for why these studies do not contradict each other, even though they assess organizational change in DT differently. Rather, they are perspectives within or across levels. However, to evaluate the nature of organizational change in DT in its entirety, a perspective on all coexisting levels is inevitable. In this realm, we bring together the different fragments of valuable existing research on different levels of analysis into one multi-level view. For research, this integration serves as a basis to consciously design studies on organizational

change in DT with respect to the identified levels. A conscious selection and communication of one or more levels under investigation allows for better comparability between research results and a unified understanding of organizational change in the context of DT.

Practical Implications

In terms of implications for managers, this subchapter answers the call for guidance on how to manage the change dynamics in the context of DT (Baiyere et al., 2021; Carroll, Hassan, et al., 2023; Petruzzelli et al., 2021). First, the DT patterns represent a comprehensive list of changes made by organizations in the context of DT, which managers can evaluate for their respective suitability in the organization's individual context. In this context, managers can analyze the status quo of their organization's DT by assessing which of the DT patterns have already been implemented or are currently underway. This assessment can serve as a conversation starter to identify the untapped potential of DT. In this realm, the results make it possible to identify the extent to which a DT theme is fulfilled by analyzing whether the corresponding DT patterns and DT initiatives have been implemented in the organization.

Second, our results suggest that the nature of organizational change is not equal in every DT. Sometimes, organizational change might be more continuous, and other times more episodic. Using the multi-level analysis framework, managers can consciously design organizational change so that the organization can withstand its impact. At the meta-level, an overall assessment can be made of how much continuous or episodic change the organization can withstand (e.g., depending on resources, cultural willingness to change, etc.), which influences the selection of DT initiatives at the micro-level. At the micro-level, managers can actively manage the change process and match their DT efforts to their capacity for change. For example, episodic DT initiatives require more resources at the point of radical change, implying the need for a large project team, while requiring fewer resources in the long run. In contrast, continuous DT initiatives require constant attention (with fewer resources) to keep the change on track, requiring permanent roles rather than short-term project teams. Depending on the current situation, managers have the flexibility to shape organizational change in DT either episodically or continuously by consciously selecting DT initiatives that match their available competencies and resources.

Limitations and Future Research

As with any other research, this subchapter has limitations that require future research. The first thing to note in this regard is that our structured literature review mainly builds on DT research

from the IS domain. Although we adhere to established guidelines and our results rely on an extensive sample of literature, our findings might be restricted in terms of the discipline focus we applied. Further insights into other focus areas of DT could potentially be generated if investigating relevant articles from other disciplines (e.g., management or computer science). We are confident that our selected constraints (i.e., keywords, databases) yielded a sufficiently representative sample of literature to analyze *what* changes in DT and *how* the associated change unfolds. In total, we analyzed 142 articles from three vantage points (i.e., high scientific rigor, broad dissemination, and renowned industry influence) that allowed us to develop a comprehensive understanding of organizational change in the context of DT.

Second, while we are confident that the DT themes are sufficiently abstracted to remain stable over time, we expect the set of DT patterns and DT initiatives presented to evolve over the coming years. The dynamic nature of emerging digital technologies triggers a speed of change that will lead to the formation of new DT patterns and DT initiatives. Therefore, the contributions regarding *what* changes will eventually need an update to account for novel development. Although we cannot predict the specifics of this evolution, the perspective of episodic, continuous, and hybrid change can be applied to emerging change constructs in the future.

Lastly, another limitation of qualitative research is that the coding process depends to certain parts on the interpretation of the subject. Although we followed the approach of Gioia et al. (2013) to ensure qualitative rigor in our inductive research, the definite assignment of data segments to specific themes and categories still was challenging. Emerging constructs affect one another, and mutual exclusivity is hard to achieve. Though, in particular, assigning a broad number of DT initiatives to DT patterns leaves room for new interpretations within other spatiotemporal contexts. Future research should therefore consider possible interdependencies between DT initiatives, DT patterns, and DT themes. Researchers can potentially reduce the number and redefine and reassign certain change constructs, especially when interpreted within new contexts.

For future research, a real-life assessment of different change types within organizations (e.g., with case studies) is promising. By implementing different types of DT initiatives (e.g., only episodic or continuous initiatives, or a mixture thereof), insights regarding the specifics of change at different levels of analysis, as well as suitable management practices to handle the

different types could be generated. Such studies would portray an extension of our findings and could further improve the scientific understanding of DT.

Concluding, given the dynamic development of digital technologies and the corresponding dynamic development of technology use, organizing, and competition, it is expected that the relevance of DT will continue to increase in research and practice. With this subchapter, we hope to advance the conceptual understanding of *how* organizational change unfolds in the context of DT while providing inspiration and initial guidance for practitioners in their efforts to drive DT. Organizations committed to digital innovation for sustainability should take account for the embedding of digital innovation in overall digital transformations. In addition, the four DT patterns on rapid prototyping, an entrepreneurial culture, ambidexterity, and the recombination of existing technologies emerge as central. However, the four patterns follow different types of change indicating that digital innovation for sustainability requires management approaches targeted at both continuous and episodic change.

4 Internal and External Environments in Digital Innovation for Sustainability

The innovation actions for digital innovation for sustainability do not occur in isolation. Instead, they are embedded in the internal organizational and external competitive environment (Kohli & Melville, 2019). In the internal environment, employees and their skills and expertise, culture, leadership, or organizational structures impact how organizations leverage digital innovation for sustainability (Kohli & Melville, 2019; Müller et al., 2019; Soluk & Kammerlander, 2021). In the external environment, customers, competitors, suppliers, and entire business ecosystems shape digital innovation (Herterich et al., 2023; Kohli & Melville, 2019; P. Wang, 2021). Subchapter 4.1 focuses on ways to prevent technology-related health risks in the internal innovation environment and conforms with M. Berger et al. (2023) for most parts. Subchapter 4.2 assesses the potential of digital innovations to understand and support customer behavior in the context of sustainable consumption.

4.1 Developing Technostress Prevention Measures for the Internal Environment

Digital technologies are ubiquitous in our private and business lives and they strongly impact how organizations innovate digitally for sustainability. Digital technologies generally facilitate work activities and enable new ways of work (Becker et al., 2020). However, the use of digital technologies (e.g., during digital innovation) may also create technostress, contributing to individuals' overall experience of stress. Thereby, technostress describes any stress from using digital technologies (Ragu-Nathan et al., 2008). It has become a severe issue with societal, economic, and personal consequences such as impaired individuals' health or decreased work productivity (Ragu-Nathan et al., 2008; Srivastava et al., 2015). For digital innovation for sustainability, this is an issue for two reasons. First, an internal environment marked by high levels of technostress is not socially sustainable, as health is one dimension of social sustainability. Second, employees affected by technostress are less successful in their innovation endeavors, limiting the potential of digital innovation for sustainability. While technostress can also have positive effects – techno-eustress (Benlian, 2020; Califf et al., 2020; Tarafdar et al., 2019) – we focus on the negative side, techno-distress (in this dissertation referred to as technostress), which is prevailing in literature (e.g., Pirkkalainen et al., 2019; Weinert et al., 2020).

Technostress is mostly described as a process, starting with *technology environmental conditions* that refer to attributes of specific digital technologies (e.g., push notifications) and represent a demand to the individual. The individual next appraises if the demand demonstrates a threat or a challenge, indicating a *technostressor*. This then leads to a *technostress response* (i.e., physiological, psychological, and coping responses). In the long term, the experienced technostress response can lead to serious adverse *technostress outcomes* including severe health impairments, such as burnout, depression, or exhaustion (Maier, Laumer, Weinert, & Weitzel, 2015). Technology environmental conditions do not necessarily lead to an adverse course of the technostress process. There exists a variety of actions that can mitigate the adverse technostress outcomes throughout the technostress process. It is, therefore, crucial to not only react after negative technostress outcomes already arose.

There is a stream of literature on technostress inhibitors (Chandra et al., 2019; Fuglseth & Sørebø, 2014; Ragu-Nathan et al., 2008; Tarafdar et al., 2015; Tarafdar et al., 2010; Tarafdar et al., 2011). Technostress inhibitors are "organizational mechanisms that have the potential to reduce the effects of technostress" (Ragu-Nathan et al., 2008, p. 422). Examples of technostress inhibitors include technical support provision or literacy facilitation (Ragu-Nathan et al., 2008). We build on the literature on technostress inhibitors, combine it with preventive stress management, and develop the notion of preventive technostress management.

The *Theory of Preventive Stress Management* can help to understand how throughout the technostress process, the experience of technostress can be reduced (Hargrove et al., 2011; J. C. Quick & Quick, 1979; J. C. Quick et al., 1997). The theory includes a time perspective on different time windows for preventing stress. The theory recommends intervening throughout the process and divides possible measures into three categories: primary, secondary, and tertiary preventive measures (J. C. Quick & Quick, 1979; J. C. Quick et al., 1997). Transferring the Theory of Preventive Stress Management into the technostress world, preventive technostress management includes *primary prevention* targeting the technostressors, thus focusing on the cause of technostress (Hargrove et al., 2011), and *secondary prevention* targeting the technostress response, thus including actions designed to improve the individual's response (e.g., improving coping skills). *Tertiary prevention* aims to treat the adverse technostress outcomes and targets the very end of the process. By contextualizing the Theory of Preventive Stress Management to the narrower context of technostress following guidelines of Hong et al. (2014), we transfer previously generated insights in prevention theory to the technostress domain as a novel, complementary viewpoint to technostress inhibition.

Prior research in the context of preventive stress management emphasizes the role of organizations in preventing individuals' stress and promoting employees' and organizations' well-being (Hargrove et al., 2011). Since many technostressors stem from digital technology use at work, organizations face the moral and legal responsibility to improve employee health by preventing excessive work-related technostress. Some countries, such as Germany, have even imposed legal requirements for organizations to assess and reduce employees' negative psychological responses (e.g., caused by technostress) at work.[6] Not only does the prevention of technostress reduce negative consequences for employees' health, but it saves organizations the costs of substituting employees on sick leave, among others. In addition, only when employees are healthy, can they effectively leverage digital innovation to create sustainability value. An analysis and comprehensive knowledge base of technostress prevention measures an organization can introduce are needed to enable organizations to reduce technostress among the employees proactively. So far, prior research has analyzed the influence of single measures (Day et al., 2012; Valta et al., 2021) or technology characteristics (Ayyagari et al., 2011; Becker et al., 2020) on selected technostressors. Given the severity of technostress outcomes, however, research needs to provide organizations with guidance on what actionable measures exist, which they can implement to prevent technostress for their employees (Brivio et al., 2018). Hence, the research aim of this subchapter is to (1) identify technostress prevention measures by bringing together different strands of research, and (2) characterize them in terms of their basic approach to preventive technostress management, their applicability in practice, and their relevance in targeting technostressors.

To achieve this aim, we synthesize and advance a knowledge base of technostress prevention measures by bringing together the research strands of technostress inhibition, further technostress literature, and stress management. We use the Theory of Preventive Stress Management as a theoretical basis that we apply to technostress. We assess characteristics for the applicability of the technostress prevention measures in practice. To do so, we conduct a structured literature review on organizational measures that can prevent technostress and reframe them into actionable technostress prevention measures. We enrich the resulting list by conducting multiple focus group workshops followed by a Delphi study with industry experts, yielding 24 validated prevention measures. Based on the experts' assessments, we produce a

[6] German Occupational Safety and Health Act of August 7th 1996 (Federal Law Gazette p. 1246), as amended by Article 1 of the Act of 22 December 2020 (Federal Law Gazette p. 3334); (Occupational Safety and Health Act, 1996)

description for each prevention measure, a classification of several characteristics, and, in the case of primary prevention measures, an indication of the technostressors they are expected to target.

4.1.1 Theoretical Background

In their daily life, people use a large variety of digital technologies, including devices such as smartphones or laptops and applications that facilitate business processes by providing tools for inter- and intra-organizational communication and collaboration (Dittes & Smolnik, 2019; Zuppo, 2012). Digital technologies shape modern work life and contribute to many positive facets of work, such as the potential to work from home or seamless collaboration across countries. For example, during the COVID-19 pandemic, digital technologies allowed many companies to uphold their operation despite stay-at-home and social distancing orders (Ketter et al., 2020). However, the intensive use of digital technologies also risks employees' health and performance. One of these risks is *technostress*. Technostress is a specific form of human stress that is triggered by the use of digital technologies (Tarafdar et al., 2019). Human stress has been extensively studied and is often explained through Lazarus and Folkman's (1984) Transactional Theory of Stress (Ayyagari et al., 2011; Ragu-Nathan et al., 2008; Tarafdar et al., 2019). The theory conceptualizes stress as a process that includes the existence of internal and external *demands* (e.g., time pressure, social conflicts), which the individual assesses in two appraisal steps. First, the individual subconsciously evaluates if the demand falls into the category of positive, irrelevant, or stressful. If categorized as stressful, the demand may threaten the individual, indicating a stressor. Next, the individual subconsciously examines if the available resources are sufficient to cope with the stressor (Lazarus & Folkman, 1984). The process is therefore followed by an interdependent cycle of physiological and psychological responses (e.g., negative emotional states) and coping (i.e., behavior in response to stressors) that run in parallel, repeatedly, and cannot be separated in time (Califf et al., 2020; Lazarus & Folkman, 1984; Tarafdar et al., 2019). This process, in turn, may lead to adverse outcomes such as decreased health or lower productivity.

Transferring the Transactional Theory of Stress into the digital world, Tarafdar et al. (2019, p. 8) describe technostress as the "stress process activated due to the use of IS". Like stress in general, technostress can be positive (techno-eustress) or negative (techno-distress) (Tarafdar et al., 2019). In the following, we focus on the negative side of the technostress process and specifically the prevention of that negative side of technostress. The technostress process is

sketched in Figure 14 based on Califf et al. (2020) and Tarafdar et al. (2019): T*echnology environmental conditions* include potential sources of a technology-related stressful situation. The individual exposed to such a demand from the environment appraises if the demand is harmful. If the demand is appraised as harmful it is a *technostressor*. Technostressors are "conditions or factors that can create stress because of ICT use" (Tarafdar et al., 2015, p. 106) and "are appraised by the individual as damaging" (Tarafdar et al., 2019, p. 9). When confronted with a technostressor, this leads to a multifaceted *technostress response*. The technostress response includes short-term physiological (e.g., the release of cortisol, adrenaline, and noradrenaline) and psychological (e.g., negative affect) responses that lead to coping responses (e.g., avoiding or stopping IS use).[7] Coping response describes "actions or emotions to overcome or deal with the threat or hindrance the individual perceives from the" technostressor (Tarafdar et al., 2019, p. 20). Examples include seeking social or technical support (Pirkkalainen et al., 2019; M. Schmidt et al., 2021; Weinert et al., 2020). Coping is undoubtedly crucial to mitigate technostress but is performed entirely by the affected individual only after the technostressor has emerged.

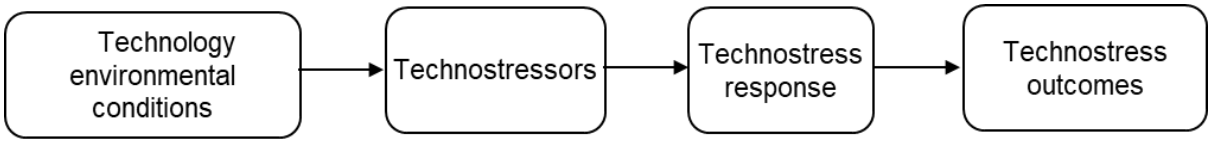


Figure 14: Technostress Process based on Tarafdar et al. (2019) and Califf et al. (2020)

In parallel, the individuals experience a psychological or physiological response like negative emotions (e.g., anxiety, hostility) or an increase in cortisol, or a fast heart beating (Califf et al., 2020; R. Riedl et al., 2012). The sequence of the psychological or physiological response and the coping response cannot be clearly separated in time and can run in parallel and repetitively. Therefore, we summarize this interdependent cycle as a technostress response, consisting of psychological, physiological, and coping responses. We define *technostress response* as an interdependent, repeatedly, and potentially parallel process of negative psychological and/or physiological states caused by the technostressor (i.e., psychological and physiological response) and the application of actions or emotions to deal with the threat of the technostressor (i.e., coping response) (based on Califf et al. (2020), Tarafdar et al. (2019), R. Riedl et al.

[7] R. Riedl et al. (2012) focus on physiological responses, Califf et al. (2020) on psychological responses, Tarafdar et al. (2019) on coping responses. In Figure 14, we follow Lazarus and Folkman (1984) in summarizing these types of responses as a general (techno)stress response, since these different responses are interdependent and not clearly separable in time.

(2012), and Lazarus and Folkman (1984)). In the long-term, the technostress response can lead to adverse *technostress outcomes*, especially when the technostress response is intense and long-lasting or frequently repeated. These include adverse outcomes for the individual, such as sleeping problems or emotional exhaustion – as well as adverse organizational outcomes like decreasing productivity, lower levels of job satisfaction, and less organizational commitment (e.g., Gimpel, Lanzl, et al., 2018; R. Riedl et al., 2012; Srivastava et al., 2015).

Technostressor	**Description**
Complexity	"Situations where the complexity associated with ICTs makes users feel inadequate as far as their skills are concerned and forces them to spend time and effort in learning and understanding various aspects of ICTs" (Tarafdar et al., 2007, p. 315).
Insecurity	"Situations where users feel threatened about losing their jobs as a result of new ICT replacing them, or to people who have a better understanding of the ICT" (Tarafdar et al., 2007, p. 315).
Interruptions	Situations in which ICTs or ICT-based sources cause the user to shift their attention away from the task they are working on at that moment (Galluch et al., 2015).
Invasion	"The invasive effect of ICTs in terms of creating situations where users can potentially be reached anytime, employees feel the need to be constantly 'connected,' and there is a blurring between work-related and personal contexts" (Tarafdar et al., 2007, p. 315).
Invasion of Privacy	Situations in which users "are becoming increasingly concerned that their privacy could be invaded by computer technologies. The problem is acerbated due to the present work pressures, which create an unspoken value that appreciates individuals who are constantly available" (Ayyagari et al., 2011, p. 841).
Overload	"Situations where ICTs force users to work faster and longer" (Tarafdar et al., 2007, p. 315).
Role Ambiguity	Situations in which "there is uncertainty as to whether an individual should expend his or her resources to perform the task requirements at work or to acquire new skills. These competing demands between the job and learning new skills constrain individual abilities" (Ayyagari et al., 2011, p. 842).
Uncertainty	"Contexts where continuing changes and upgrades in an ICT unsettle users and create uncertainty for them, in that they have to constantly learn and educate themselves about the new ICTs." (Tarafdar et al., 2007, p. 315)
Unreliability	"System malfunctions and other IT-hassles" (T. Fischer & Riedl, 2015, p. 1462) that are caused by ICTs that are perceived to increase workload due to the necessity to repeat tasks (Ayyagari et al., 2011).

Table 8: Overview of Technostressors

Several technostressors have been discussed in the literature. Tarafdar et al. (2007) and Ragu-Nathan et al. (2008) were the first to develop and empirically validate scales for five technostressors: *overload*, *invasion*, *complexity*, *insecurity*, and *uncertainty*.[8] In subsequent research, these technostressors have been applied in many studies in different contexts and are well-established today (e.g., Becker et al., 2020; Fuglseth & Sørebø, 2014; Maier et al., 2019; Pirkkalainen et al., 2019). In another seminal technostress study, Ayyagari et al. (2011) identify *unreliability*, *role ambiguity*, and *invasion of privacy* as additional technostressors. Further, Galluch et al. (2015) and Tams et al. (2018) propose technology-enabled *interruptions* as another technostressor in work environments. While various other technostressors have been suggested in the literature (e.g., T. Fischer et al., 2021; Maier et al., 2012; Maier, Laumer, Weinert, & Weitzel, 2015), we did not consider them in this dissertation because they are either specific to a particular technology, can be subsumed under another technostressor, or were published after the start of the Delphi study. The nine mentioned technostressors included in this research are presented in Table 8.

4.1.2 Theoretical Model

The Theory of Preventive Stress Management, originally developed by J. C. Quick and Quick (1979), has roots in preventive medicine and public health. Nowadays, it is well established (Hargrove et al., 2011; J. C. Quick et al., 1997). The theory provides general principles of preventive stress management and tells us that there exists a variety of specific actions that can reduce stress throughout the stress process (J. C. Quick & Quick, 1979). We contextualize the Theory of Preventive Stress Management to technostress (Hong et al., 2014).

Hong et al. (2014) suggest different approaches to incorporating context in theorizing. According to their typology, we engage in single-context theory contextualization with the domain of interest being technostress at work and the Theory of Preventive Stress Management as a well-established general theory. We consider concepts from both technostress theories and the Theory of Preventive Stress Management and explain their interrelations based on the underlying theory (level 2a contextualization from Hong et al. (2014)). This leads us to the conceptual model of preventive technostress management presented here. In the subsequent paragraphs, we decompose core constructs (specifically "primary technostress prevention

[8] The original naming used the prefix "techno-" for each of these technostressors. We omit this prefix for brevity. Tarafdar et al. (2007), Ragu-Nathan et al. (2008) and others use the term 'technostress creator' rather than 'technostressor.' We treat these terms as synonyms and follow Tarafdar et al. (2019) in using technostressor.

measures" and "secondary technostress prevention measures") into contextualized constructs (i.e., 24 specific technostress-prevention measures; level 2c contextualization from Hong et al. (2014)). In that, we follow guidelines suggested by Hong et al. (2014): We perform a thorough literature-based and expert-based evaluation of the technostress context to identify specific factors. In that, we adapt the principles of preventive stress management to the technostress context and decompose core high-level constructs of the Theory of Preventive Stress Management. As our principles of preventive technostress management and the prevention measures are manifestations of general constructs from the Theory of Preventive Stress Management, their effects can be explained based on the theoretical rationale of the general theory.

J. C. Quick and Quick (1984b, p. 146) defined preventive stress management as "an organizational philosophy and set of principles that employ specific methods for promoting individual and organizational health while preventing individual and organizational distress." It is important to note that the Theory of Preventive Stress Management takes a broader view of stress than the technostress theory. As the definition of preventive stress management shows, stress is seen as a phenomenon at the individual and organizational levels. The Theory of Preventive Stress Management considers stress an overarching rubric for how individuals and organizations react and adjust to their environments. It becomes specific for the concepts of stressor, stress response, and stress. J. C. Quick et al. (1997, p. 6) distinguish between individual stress and organizational stress, with the latter being "the degree of deviation an organization experiences from a healthy, productive level of functioning." Stress is not bad per se – it can have positive and constructive outcomes that support performance. However, "excessive, prolonged, intense, or mismanaged stress at the workplace" result in physiological, psychological, and behavioral deviations from an individual's healthy functioning (J. C. Quick et al., 1997, p. 18). The aggregate of this individual-level stress becomes organizational stress. This conceptualization of stress and, specifically, stress outcomes on the organizational level is uncommon for technostress research. However, it is compatible with technostress research suggesting that the organizational environment, including the technological environment, is an important determinant of technostress (e.g., Tarafdar et al., 2019) and it is in line with research on technostress inhibitors as organizational mechanisms to reduce technostress (e.g., Ragu-Nathan et al., 2008).

The Theory of Preventive Stress Management builds on five guiding principles which are applicable to technostress management (J. C. Quick et al., 1997). The five principles of (techno)stress management are:

(1) Individual and organizational health are interdependent. Organizations cannot achieve goals like high productivity or flexibility without healthy individuals. This principle contributes to the need for organizations to develop preventive technostress management as part of their overall management of employee health and safety.
(2) Leaders have responsibility for individual and organizational health. This leadership challenge and responsibility includes diagnosing technostress issues in the organization and selecting and implementing related technostress prevention measures. Leadership is responsible for technostress management; however, all employees are responsible for their health and their co-workers' health.
(3) Individual and organizational stress is not inevitable. The Theory of Preventive Stress Management suggests that preventive managerial actions may mitigate stress. For this, they must anticipate and influence stressors and stress processes. This subchapter's practical contribution relates to the second and third guiding principles in supporting leaders in selecting adequate technostress prevention measures.
(4) Each individual and organization reacts uniquely to stress. This is well in line with technostress theories and suggests that preventive technostress management needs to be tailored to specific organizations and needs to allow flexibility for individuals.
(5) Organizations are ever-changing, dynamic entities. This implies that preventive technostress management cannot be a one-time effort but needs to be constantly evaluated and developed to meet the interests of the organization and the employees.

Beyond these principles, the Theory of Preventive Stress Management considers the stress process and a translated overlay which is composed of preventive interventions (Hargrove et al., 2011; J. C. Quick & Quick, 1979; J. C. Quick et al., 1997). One fundamental premise of preventive medicine is that preventive measures can target each stage in the life history of a disease to slow, stop, or revert the progression of it. Applied to stress, this means preventive measures can address various points in the stress process: "Primary prevention is aimed at modifying the organizational stressors that may eventually lead to stress. Secondary prevention aims at changing individual stress responses to necessary demands. Tertiary prevention attempts to minimize the amount of individual and organizational stress that results when

organizational stressors and resulting stress responses have not been adequately controlled" (J. C. Quick et al., 1997, p. 154).

Building on J. C. Quick and Quick (1984b), we define preventive technostress management as an organizational philosophy and set of principles that employ specific measures to inhibit technostress to promote individual and organizational health. The set of five principles is described above. The measures are technostress prevention measures. Figure 15 positions the prevention measures along the technostress process. It is important to note that secondary and tertiary prevention are not alternatives but complements of primary technostress prevention (J. D. Quick et al., 1998). In general, excessive, prolonged, and intense technostress that will eventually lead to adverse outcomes at the individual level and, consequently, on the organizational level should be prevented as early as possible.

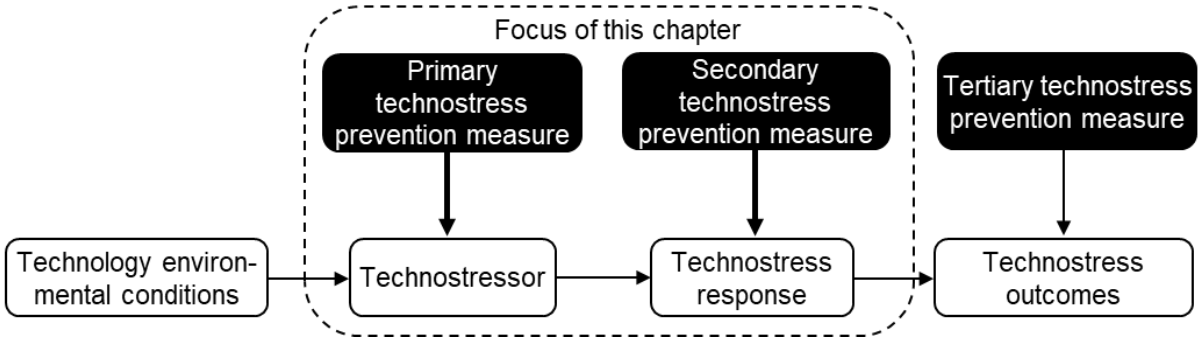


Figure 15: Conceptual Model of Preventive Technostress Management, Adapted from Tarafdar et al. (2019), Califf et al. (2020), and J. C. Quick et al. (1997)

Technostress inhibitors and technostress prevention are related. Prevention takes measures to inhibit technostressors, technostress responses, or adverse technostress outcomes. Comparing research on technostress inhibitors to the previously presented insights on preventive stress management shows that the terms are based on the same theorization in the technostress process and refer to avoiding technostress to promote individual and organizational health. As summarized by Sarabadani (2018), technostress inhibitors are theorized to either (1) act as antecedents to technostressors, hence reducing the technostressor itself (Jena, 2015; Tarafdar et al., 2015; Tarafdar et al., 2011), (2) moderate the relationship between technostressor and outcomes (Ragu-Nathan et al., 2008), or (3) decrease the adverse outcomes (e.g., job satisfaction, sales performance, organizational commitment) directly (Jena, 2015; Ragu-Nathan et al., 2008; Tarafdar et al., 2011). These three mechanisms of technostress inhibitors align well with the three stages of prevention (primary, secondary, and tertiary).

The terminology of prevention has not been widely used in the context of technostress. Only Salo et al. (2017) used the foundation of LaMontagne et al. (2007), which is based on the Theory of Preventive Stress Management, to structure individuals' ways of reducing technostress without introducing the term technostress prevention. Salo et al. (2017) categorized five different individual measures into stressor reduction (e.g., modification of IT features), stressor toleration (e.g., modification of personal reactions to IT stressors), and recovery from strain (e.g., online/offline venting). Building on the work of LaMontagne et al. (2007), this classification is equivalent to the classification of primary, secondary, and tertiary technostress prevention measures. However, while Salo et al. (2017) study individuals' coping with technostress, preventive stress management theory emphasizes the duty of organizations to promote individual and organizational health and to minimize individual and organizational stress to create an organization in which their employees can thrive and produce (Hargrove et al., 2011; J. C. Quick et al., 1997). We proceed to use the term *technostress prevention measure* to build on the existing knowledge of preventive stress management. We integrate both existing knowledge on technostress inhibitors and the differentiation between primary, secondary, and tertiary preventive measures in the conceptual model of preventive technostress management (Figure 15). The model is based on the technostress process of Tarafdar et al. (2019) and Califf et al. (2020), synthesized with the Theory of Preventive Stress Management in organizations (Hargrove et al., 2011; J. C. Quick & Quick, 1979; J. C. Quick et al., 1997).

In analogy with general stress prevention (J. C. Quick et al., 1997), we characterize the three technostress prevention stages as follows: *Primary technostress prevention* is technostressor-directed. It targets reducing the frequency, duration, and/or intensity of one or multiple technostressors. The Theory of Preventive Stress Management refers to organizational stressors as it focuses on work stress. These organizational stressors result from task, role, physical, and interpersonal demands. Specifically for technostress, the organizational stressors are activated due to the use of IS (technostressors). These (techno-)stressor-directed interventions are located at the onset of the (techno-) stress process directly related to the (techno-)stressors and represent the most efficient and effective means of prevention (J. C. Quick & Quick, 1979). One example of primary technostress prevention is the development of team norms or reachability rules to avoid work-related communication when not appreciated.

As primary prevention might not be effective for all individuals and in every setting, secondary stress prevention aims at improving how individuals respond to the respective stressor (J. C. Quick et al., 1997). Hence, secondary prevention is response-directed. *Secondary technostress*

prevention aims at improving the individuals' technostress responses consisting of coping responses and psychological and physiological responses. An example of a secondary technostress prevention measure is providing an ICT helpdesk. At this point, the differentiation between secondary technostress prevention measures and technostress coping becomes apparent: technostress coping refers to the behavior an individual adopts when affected by a technostressor (e.g., calling the ICT helpdesk or seeking social support). Secondary technostress prevention measures are organizational-level measures that aim at improving the individual coping skills or resources and positively influence the psychological or physiological responses, for example, by offering platforms to exchange experiences on ICT use, training to improve individual coping skills, or the setup of an ICT helpdesk. Secondary technostress prevention measures do not concern the actual execution of the coping response but aim to optimize the possibility of coping.

Construct	**Definition**
Technostress[9]	Negative "stress process activated due to the use of IS" (Tarafdar et al., 2019, p. 8) including technology environment conditions, technostressors, technostress responses, and adverse outcomes for the individual and the organization.
Technology environmental conditions	Attributes or features of the information and communication technologies that surround individuals at work (Ayyagari et al., 2011; Becker et al., 2020).
Technostressors	"Conditions or factors that can create stress because of ICT use" (Tarafdar et al., 2015, p. 106).
Technostress response	An interdependent, repeatedly, and potentially parallel process of physiological and/or negative psychological states caused by the technostressor (i.e., physiological and psychological response) and the application of actions or emotions to deal with the threat of the technostressor (i.e., coping response) (based on Califf et al. (2020), Tarafdar et al. (2019), and R. Riedl et al. (2012).
Technostress outcomes	Individual strains (i.e., physiological, psychological, and behavioral consequences) and adverse organizational outcomes caused by technostress (Ragu-Nathan et al., 2008).
Technostress inhibitors	"Organizational mechanisms that have the potential to reduce the effects of technostress" (Ragu-Nathan et al., 2008, p. 422).
Preventive technostress management	An organizational philosophy and set of principles that employs specific measures to inhibit technostress to promote individual and organizational health (adapted from J. C. Quick and Quick (1984b)).

[9] Note that this definition of technostress follows the dissertation's focus on techno-distress.

Construct	Definition
Primary technostress prevention	Taking measures for reducing, modifying, or managing technostressors' frequency, duration, and/or intensity (adapted from J. C. Quick et al. (1997)).
Secondary technostress prevention	Taking measures for improving individuals' psychological, physiological, and coping responses to technostressors (adapted from J. C. Quick et al. (1997)).
Tertiary technostress prevention	Taking measures for the treatment, compensation, and rehabilitation from adverse individual or organizational technostress outcomes (adapted from J. C. Quick et al. (1997)).

Table 9: Summary of Technostress Constructs

Tertiary technostress prevention concerns the treatment, compensation, and rehabilitation of adverse individual or organizational technostress outcomes (Hargrove et al., 2011; J. C. Quick et al., 1997). These interventions are outcome-directed. As they intervene after the onset of adverse outcomes (e.g., burnout or depression regarding individual health outcomes), they are at the individual level mainly related to medical or psychiatric treatments. This is why we focus on primary and secondary but not tertiary technostress prevention.

Table 9 provides an overview of the key constructs of our conceptual model of work-related technostress prevention and their definitions.

4.1.3 Research Methodology

We conducted a Delphi study with 13 experts from research and practice (Figure 16) to achieve our research aim of (1) identifying actionable technostress prevention measures and (2) characterizing them in terms of their basic approach to technostress prevention, their applicability in practice, and in case of primary technostress prevention measures, their relevance in targeting technostressors.

To provide an appropriate starting point for the Delphi study based on theoretical and practical knowledge, we included a preliminary phase 0 to prepare a sound set of potential technostress prevention measures from literature on technostress prevention, inhibition and related technostress literature, that investigate measures to reduce the effect of technostress. Thereby, theoretical knowledge was drawn from a structured literature review (Webster & Watson, 2002) on measures that may be qualified to prevent work-related technostress. To validate and expand the list of technostress prevention measures, we conducted two focus group workshops (Kitzinger, 1995) with experts from research and practice before conducting phases 1-3 of the

Delphi study. The central part of the Delphi study builds on these measure candidates to, again, validate, but especially to detail the technostress prevention measures. Since literature has not yet produced and documented extensive knowledge on the characteristics of technostress prevention measures, an exploratory qualitative research method is appropriate.

Unlike other exploratory qualitative research methods, Delphi studies support explorative, consensus-seeking research such as problem identification, concept development, and prioritization and have become a popular research method in IS research (Okoli & Pawlowski, 2004; Skinner et al., 2015). The iterative design of Delphi studies allows participants to learn from each other over a longer period of time, reflect on their opinions, and collectively develop results. The Delphi study addresses the research question by (1) evaluating the list of technostress prevention measures concerning relevance, completeness, and understandability, (2) characterizing the technostress prevention measures, and (3) relating the primary technostress prevention measures to the nine considered technostressors presented in Subchapter 4.1.2.

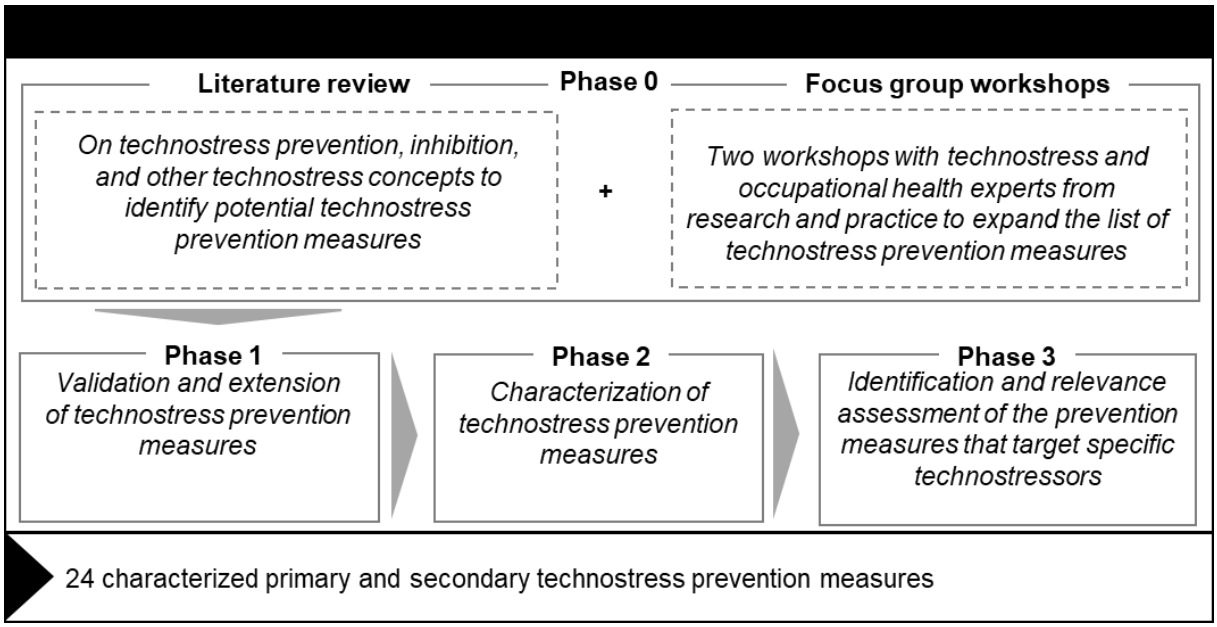


Figure 16: Research Process for Technostress Prevention

Phase 0: Structured Literature Review and Focus Group Workshops

We conducted a structured literature review to identify known measures for reducing and eliminating technostress, which can be interpreted and converted into technostress prevention measures (Webster & Watson, 2002). In theory, coping is not part of primary and secondary prevention. We nevertheless included it as a search term because some scholars provide examples of coping measures that can be used as input to develop technostress prevention

measures. One reason for the lack of clear concepts could be the novelty of technostress prevention within the research stream. As suggested by vom Brocke et al. (2015) and Webster and Watson (2002), the literature review comprised three phases: (1) literature search, (2) selection of relevant literature, and (3) analysis of the results.

We defined a search string, databases, and inclusion and exclusion criteria (vom Brocke et al., 2015). As the literature on technostress prevention is highly dispersed and often described under different terminology, we chose a broad search string that considers adjacent concepts and literature from various disciplines (information systems, organizational science, health, and psychology). Therefore, we searched for topics, abstracts, titles, and keywords that matched the search string ((“technostress” OR “techno stress” OR “digital stress”) AND (“prevent*” OR “reduc*” OR “mitigat*” OR “overcome” OR “cop*” OR “inhibit*”)) in the three databases Web of Science, PubMed, and AISeL as well as in the Journal of Business Economics. In total, we found 204 articles. After filtering for English, peer-reviewed, full research articles (n = 192), removing duplicates (n = 167), and adding previously known articles according to Larsen et al. (2019) our set consisted of 171 articles. Based on our selection criteria, we conducted a three-step selection process, including title, abstract, and full-text review (Levy & Ellis, 2006; Okoli, 2015). The selection criteria included: (1) the article is within the domain of technostress, and (2) the article includes at least one recommendation for preventing technostress (at work/in organizations) following our definition of technostress prevention measures. After the title screening, 102 articles remained. The abstract screening excluded an additional 42 articles, resulting in 60 articles that went into detailed analysis. For details, please see Appendix C.1. Finally, the full-text screening resulted in a list of 40 relevant articles out of which seven articles belong to the specific domain of technostress inhibition, while the remaining 33 articles result from the additional terms in the search string (Appendix C.2).

Independently from the literature review, we conducted two focus group workshops with technostress and occupational health experts from research and practice (Appendix C.3) to potentially expand the list of technostress prevention measures. The workshops aimed to identify recent or modern concepts for dealing with technostress that are being applied in practice but are not (yet) embedded in literature. Therefore, in the first focus group workshop, eight experts from practice and four from research developed a set of technostress prevention measures guided by a moderator and a minute taker (Conklin & Hayhoe, 2010). The participants’ areas of expertise include information systems, psychology, and occupational health and safety. The workshop’s procedure was inspired by Then et al. (2014). The

participants collected and discussed possible technostress prevention measures that organizations can take by making targeted changes to technologies, organizations, or individuals. A second moderated workshop with five experts (four from practice, one from research) expanded on the first workshop's results. The participants were introduced to the technostressors to develop adequate technostress prevention measures. To guarantee the privacy and foster an open atmosphere, we refrained from recording and transcribing the workshops. Instead, we created a photo protocol by taking photographs of the final whiteboards and collected the focus groups' notes as field notes (Miles & Huberman, 1994) – a valid qualitative data source in workshops (Ørngreen & Levinsen, 2017). Based on this information, the moderators of the two workshops summarized the results and prepared them for the participants. The participants then had the opportunity to add to or adjust the summaries until all participants were satisfied.

With the two workshops, we collected 94 technostress prevention measure candidates on different levels of detail. From the 40 relevant literature articles, we extracted 34 distinct recommendations for preventing technostress. Two researchers jointly categorized the measure candidates, grouped them on the same level of detail, and fitted them to our definition of technostress prevention. This procedure yielded an initial list of 24 technostress prevention measures that went into the Delphi study. We used the detailed technostress prevention measure candidates to describe and exemplify the aggregated technostress prevention measures. We formulated the underlying inhibiting effect and a measure's description based on both input sources during this process.

Phases 1, 2, and 3: The Delphi Study

Our research is a slightly modified ranking-type Delphi study (R. C. Schmidt, 1997), a common Delphi study approach (Paré et al., 2013). The ranking-type Delphi study proposed by R. C. Schmidt (1997) consists of three phases: (1) brainstorming to discover the issues, (2) narrowing down to determine the most important issues, and (3) ranking the issues. Similar to other published Delphi studies (Paré et al., 2013), we merged the first and second phases because the literature review and the focus group workshops in phase 0 already structured the topic. Instead, we added a phase for characterizing each technostress prevention measure. Each phase consisted of two rounds to validate the previous round's result, which is appropriate for producing credible results (Skinner et al., 2015). Consequently, our Delphi study consisted of three phases:

(1) Validation and extension of technostress prevention measures
(2) Characterization of technostress prevention measures
(3) Identification and relevance assessment of primary technostress prevention measures that target specific technostressors

To ensure that the participants of our Delphi study are knowledgeable experts in technostress and are aware of the issue in the larger world around them (Delbecq et al., 1975; Keeney et al., 2006; Skinner et al., 2015), we applied the following selection criteria (Okoli and Pawlowski 2004): experts should (1) be responsible for, for example, occupational safety/medicine, psychological risk assessment/operational health management, or human resources, (2) have experience in the field of technostress, stress management, or occupational health and safety, (3) have at least three years of work experience, and (4) be frequent users of ICTs themselves. These requirements ensured that all experts were familiar with technostress and possible technostress prevention measures. We ensured that all experts professionally deal with stress management programs (all work on general occupational stress management; some focus on technostress management). Not every expert had experience with all measures presented but at least with multiple technostress prevention measures. Thus, they can assess the measures, evaluate them, and estimate the implementation. Experts had the choice not to provide assessments on individual measures when they felt they had insufficient information or experience with the measure. But this option was never used in the Delphi study. We have no indication for systematic differences in the assessment of measures by the experts depending on the expert's first-hand experience with a measure as compared to only abstract knowledge about the measure. Such differences could have occurred in phases 2 to 3. In the progression of the Delphi study, the experts' assessments tended to converge, given even less basis to differentiate by experience. Hence, we report aggregate results from the entire panel.

To ensure broad topic coverage, we recruited experts from different industries and company sizes via our industrial network and several occupational health and safety events on the topic of technostress. We reached out to a total of 50 possible experts. Of those, 15 experts fulfilled the selection criteria and agreed to participate in our Delphi study. None of them participated in the focus group workshops in Phase 0. One participant missed the first round, and another dropped out after the first round. Thus, 13 experts completed each round, an appropriate panel size (Linstone & Turoff, 2002; Paré et al., 2013). Appendix C.3 provides additional information on the panel.

The Delphi study took place via the online survey tool LimeSurvey and lasted five months (August to December 2020). In each round, we invited all experts to participate via e-mail and provided detailed instructions. To provide the experts with sufficient guidance, we e-mailed them their answers and suggestions from the previous round, an overview of the changes made based on all experts' suggestions, and descriptive information on quantitative evaluations after each round. Thereby, the experts could reflect on their opinion based on the aggregated results from all experts. Also, experts could provide free text feedback in addition to quantitative assessments. Through the free text feedback, we also provide the opportunity to state that one has had too little experience with the measure for assessing it. Following the suggestion of Strasser (2016), Okoli and Pawlowski (2004), and Skinner et al. (2015), participants were not known to each other by name, and we did not show the individual results of other panelists to ensure anonymity and avoid bias.

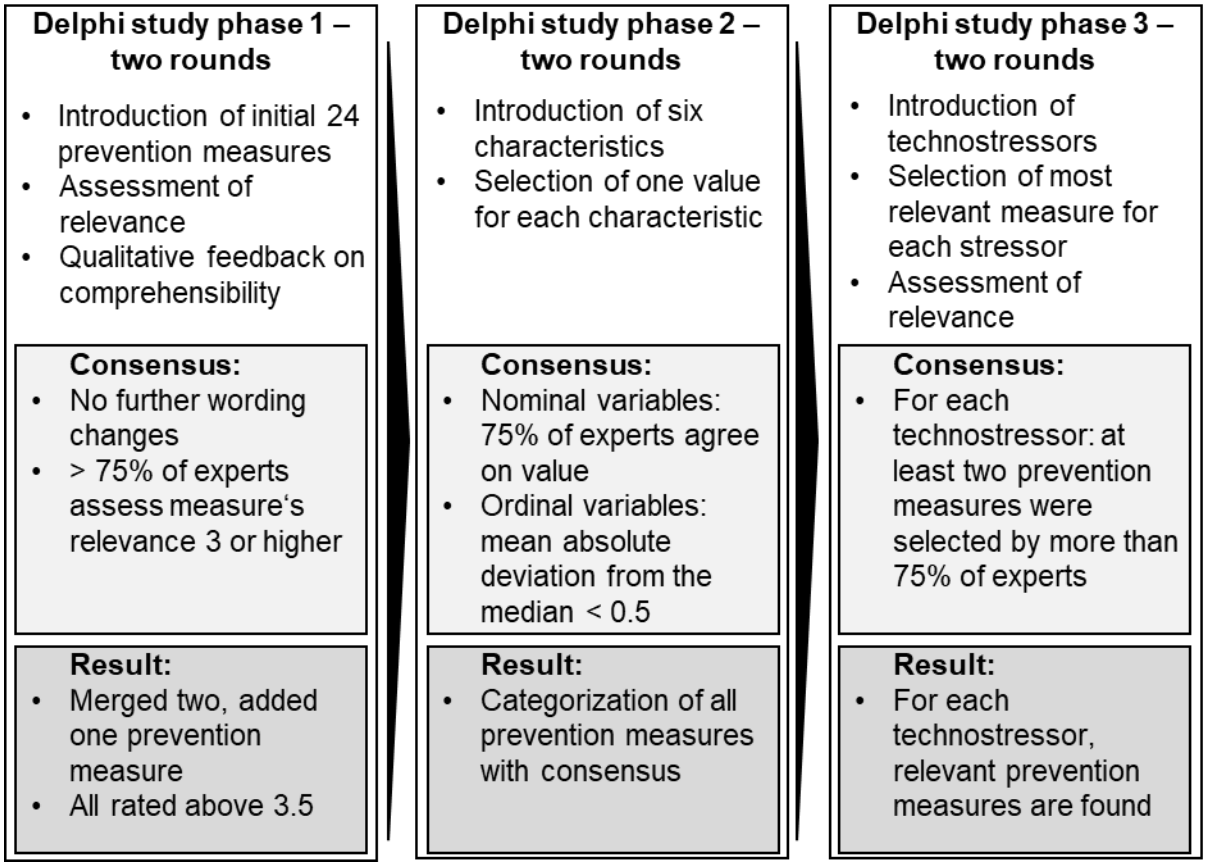


Figure 17: Overview of Delphi Study Phases

Phase 1 introduced the experts to the 24 technostress prevention measure candidates and suggested a description of each measure and their inhibiting effects. We asked the experts to rate each technostress prevention measure's relevance for preventing technostress on a scale

ranging from 0 (”not relevant”) to 6 (“highly relevant”). Literature on the Delphi method suggests to identify the key issues (Paré et al., 2013) or most important issues (R. C. Schmidt, 1997) in the respective context – in our case, the most relevant prevention measures. Relevance in general refers to (1) a relation between two entities in a context, (2) to an intention, and (3) to an assessment of the effectiveness of the relation regarding the intention (Cosijn & Ingwersen, 2000; Saracevic, 2007). The context is technostress at work, and the relation is between technostress prevention measures and parts of the technostress process. Specifically, primary prevention measures relate to technostressors, while secondary prevention measures relate to technostress responses (also see Figure 15 for the underlying model). The intention is to prevent technostress. Effectiveness relates to the ability of a measure to reduce technostress, i.e., mitigate technostressors (primary prevention) or mitigate negative stress responses (secondary prevention). Hence, we define the relevance of a technostress prevention measure as the assessment of the measure’s effectiveness in preventing the negative effects of technostress. The experts’ judgment on relevance thus inherently relates to the expected effectiveness of a prevention measure. Directly assessing effectiveness is not possible in a Delphi study. Assessing expected or perceived effectiveness would in principle be possible in a Delphi study. However, using the term effectiveness might be perceived to suggest a level of precision of measurement that our Delphi study could not deliver. Hence, we asked the experts to assess the broader concept of relevance.

We queried qualitative feedback regarding each measure’s evaluation and overall comprehensibility by providing optional text fields. Additionally, the experts were asked to review the entire list, emphasizing its completeness regarding the most relevant technostress prevention measures and adding further measures if necessary. For evaluating this phase, we examined the written qualitative feedback and the relevance assessment. We defined consensus on the technostress prevention measures’ relevance as a state in which (1) the experts mention no further wording changes or new technostress prevention measures and (2) more than 75% of the experts assess each measure’s relevance with a score of 3 (middle option) or higher. To avoid bias by individual experts, recommendations for description changes or additions of technostress prevention measures were only implemented if at least two experts made suggestions in that direction. The experts did not yet reach a consensus in the first round. Based on their feedback, two measures of the initial set were merged, and one new measure was added. In the second round, we presented the aggregated results of the first round to the experts. This round resulted in a consensus, yielding the final set of technostress prevention measures. To

take a first step toward the technostress prevention measures' categorization, three authors separately grouped the technostress prevention measures into primary and secondary preventions based on the measures' descriptions. For each measure with different categorizations of the three researchers, they discussed them together until they agreed. Figure 17 summaries key aspects of this first phase and the following phases.

Phase 2 introduced the experts to different characteristics of technostress prevention measures through short explanatory descriptions and figures. The characteristics were developed by the research team with the help of practitioners from organizational health and safety and represent a valuable step to better understand technostress prevention. Each expert could indicate one manifestation for each characteristic. The six characteristics are:

(1) **Entity of change** describes whether the technostress prevention measure alters an organization's (1) technology, (2) organizational structures and procedures, or (3) the individuals' skills and abilities (based on Murphy and Sauter (2004)). Technology, organizational structures, and organizational procedures relate to the technology environment conditions. Individual skills and abilities relate to the individual perceiving and assessing demands from the environment. Each of the three levels refers to the entity affected by the measure, which is always implemented by the organization to prevent technostress (in line with principle 3 of (techno)stress prevention).

(2) **Target group** describes whether the technostress prevention measure targets (1) all employees, (2) management only, or (3) other specific groups. This characteristic again relates to Principle 4 of (techno)stress prevention management as the first step to account for the heterogeneity of individuals. Specifically considering management relates to principle 2 which places a specific responsibility on the leadership team that serves as a role model and determines essential aspects of the employees' work environment.

(3) **Organization size** determines if the technostress prevention measure is suitable for organizations with at least (1) one or more, (2) ten or more, (3) 50 or more, (4) 250 or more, (5) 500 or more, or (6) 2,500 or more employees. Principle 4 of (techno)stress prevention management suggests that not all organizations are alike. Including the organization size is one broad category in the direction of accounting for the heterogeneity of organizations.

(4) **Duration of implementation and time to operational use** distinguishes between technostress prevention measures that take (1) less than one year, (2) 1-3 years, or (3) more than three years to become operational. While the principles of (techno)stress management suggest that stress is not inevitable (principle 3) and that leaders should select and implement technostress prevention measures, this process cannot happen instantaneously. Characterizing the duration between the selection of a prevention measure to be implemented until this measure is operational captures one element of time lack in realizing the effects of technostress prevention management.

(5) **Time until the effect of the technostress prevention measure is realized in the operational business** can take (1) less than half a year, (2) 0.5-1 year, or (3) more than one year. Individual and organizational health are interdependent (principle 1), and both individuals and organizations react (principle 4). However, this reaction is not instantaneous upon the use of prevention measures but may take time. Characterizing the time from the operational use of a prevention measure until the effects of the measure are realized on the induvial and organizational levels is the second element of time lack in realizing the effects of technostress prevention management.

(6) **Duration of the technostress prevention measure's effect** may be (1) less than one year, (2) 1-3 years, or (3) more than three years. A technostress prevention measure implemented may have long-term effects, but the effect may also fade out. One reason is that organizations are ever-changing, dynamic entities (principle 5). Hence, characterizing the duration of the effect aims at informing technostress prevention management regarding the likely need to repeatedly reassess the state of technostress and its prevention in an organization.

In both rounds of Phase 2, we evaluated the results based on the characteristics' mode (for nominal characteristics 1 and 2) and the characteristics' median (for ordinal characteristics 3, 4, 5, and 6). For characteristics with a nominal scale, the consensus is reached if 75% of the experts agree on the same characteristic (i.e., the mode). For characteristics with an ordinal scale, we defined consensus as an average absolute deviation from the median below 0.5. To further evaluate the consensus between the experts, we calculated Fleiss' Kappa for all six characteristics. The received values range from 0.01 to 0.43 in round 1 of Phase 2. Here, experts had not yet consensus. In round 2 of Phase 2, Fleiss' Kappa increased to 0.79-1.00. Except for organization size (0.79, substantial agreement), all Fleiss' Kappa values indicate an almost

perfect agreement (Landis & Koch, 1977). Again, consensus on the characterization of the technostress prevention measures was reached after two rounds.

In *Phase 3*, the experts were given a definition and an illustrative example of each technostressor as presented by Gimpel, Berger, et al. (2020). The experts then selected the prevention measures expected to be most relevant for mitigating each technostressor. In the following, we discuss the relevance of prevention measures for specific technostressors. As the results are based on expert assessments in a small sample, we do not indicate absolute and quantifiable relationships but use relevance as a measure for giving a trend statement on the expected relationship. The trend statements serve as the foundation for potential statistical analyses in the future.

For primary technostress prevention measures, this means that the measure is expected to reduce the corresponding technostressor directly. For secondary prevention measures, we do not present this relationship because one technostressor can trigger several technostress responses and one technostress response can be triggered several technostressors. Therefore, the association of the relevance relationship between secondary prevention measures and technostressor is not meaningful. Based on the results, we assess both the set of primary technostress prevention measures relevant for each technostressor as well as the set of technostressors to which a single primary technostress prevention measure is expected to be relevant. We asked the experts to assess the relevance of the selected technostress prevention measures for the specific technostressor on a scale ranging from 0 (“not relevant”) to 6 (“highly relevant”). To evaluate the connections between technostressors and technostress prevention measures, we counted how often each technostress prevention measure was selected for each of the nine considered technostressors. We declared consensus when five or more technostress prevention measures were selected by more than 75 % of the experts (that is, at least ten experts). In the second round, all technostressors met this criterion. Accordingly, the Fleiss’ Kappa values indicating the degree of agreement between the experts for each of the nine considered technostressors increased from 0.09 to 0.33 in round 1 to 0.72 (substantial agreement) to 0.94 (almost perfect agreement) in round 2 of Phase 3.

Lastly, based on our overall results, we present propositions that contain insights gained through applying the Theory of Preventive Stress Management to technostress and knowledge developed throughout our structured literature review, focus group workshops, and the Delphi study.

4.1.4 Results

Overview on Technostress Prevention Measures

Our research process resulted in a list of 24 technostress prevention measures, out of which 17 measures can be categorized as primary technostress prevention and seven as secondary technostress prevention measures (Table 10). Primary technostress prevention measures include, for example, the implementation of reachability management. By establishing reachability management, such as defining when employees are available for work-related communication, technostressors can be reduced. In contrast, secondary technostress prevention measures include the provision of ICT support. Assisting employees with fast and competent support for technical issues using ICTs allows them to better response to technostressors. The individual technostress response consists of coping responses and psychological and physiological responses. Table 10 presents the complete list of the 24 technostress prevention measures. The technostress prevention measures are sorted by their basic approach to technostress prevention. The column 'Inhibition?' indicates if the measure has been mentioned in any technostress inhibition article.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
Primary Technostress Prevention Measures					
Enabling Changes to Technology					
1	Focus the ICT landscape	no	- (new)	Establishing an ICT landscape that meets job-specific requirements can reduce the frequency, duration, and/or intensity of technostressors.	The company reduces the selection of available technologies to a reasonable level and avoids redundancies of systems and information. Employees are involved in the selection process and can use the appropriate media for a given situation (e.g., a chat for informal agreements).
2	Adapt a stress-sensitive digital workplace design	no	2	Adapting a digital workplace to the needs of employees can reduce the frequency, duration, and/or intensity of technostressors.	The design of workplaces in the organization regards ergonomic aspects and technostressors, for example, by integrating rest areas and (digitally enabled) creative or group rooms. As a result, employees can use an environment suitable for their individual digital work situations.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
3	Apply human-centered release management	yes	7	Establishing good planning and consideration of employees' needs for technology-related changes in the form of updates can reduce the frequency, duration, and/or intensity of technostressors.	For good release management, the company bundles changes to ICTs and works towards an effective ICT infrastructure. The change of ICTs is oriented towards the employees' needs, which are collected through formats such as the helpdesk or the mentor. Likewise, "inexperienced" employees are involved in the survey of needs. The effectiveness of the ICT infrastructure is regularly reviewed and provided in sufficient capacity.
4	Apply human-centered ICT design	yes	5	Tailoring ICTs to the needs of employees can reduce the frequency, duration, and/or intensity of technostressors.	ICTs are designed regarding the reduction of technostressors and are improved through continuous user involvement. Technologies that are intuitive to use and ergonomic are preferred. For example, inefficient ICT interfaces are reduced, and work-relevant information is made accessible barrier-free and straightforward. Employees have an active involvement in changes at an early stage.
5	Use gamification	no	- (new)	Using playful and rewarding elements in ICTs can reduce the frequency, duration, and/or intensity of technostressors.	ICTs are expanded in a reasonable scope to include playful elements that motivate employees, for example, by collecting points for the use of ICTs. The use of gamification should be implemented voluntarily and professionally to avoid performance monitoring.
Enabling Changes to Organizational Structures and Routines					
6	Foster a cooperative culture	yes	8	Fostering a cooperative (rather than competitive) culture with digitalization as a common goal can reduce the frequency, duration, and/or intensity of technostressors.	The company defines guiding principles and develops and establishes a digital-compatible and cooperative culture. Employees' active involvement and role model by managers help implement the culture long-term and sustainably.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
7	Develop a mission statement for digital collaboration	no	5	Fostering open communication and high transparency regarding the requirements and expectations in dealing with ICTs can reduce the frequency, duration, and/or intensity of technostressors.	An interdisciplinary team develops a company-wide mission statement for digital collaboration in a participatory way. The way of communication through and with ICTs will be clearly defined company-wide and followed up in the long term.
8	Introduce an employee data security concept	no	1	Providing transparency over how work-related data collected by technology is processed and used, particularly in performance monitoring, can reduce the frequency, duration, and/or intensity of technostressors.	The company introduces a data security concept regarding the accessibility, use, and processing of information and data regarding employees' behavior. The concept is regularly communicated transparently to the workforce. The data security concept is revised and updated regularly to ensure that it is up to date.
9	Agree on binding ICT usage guidelines	no	- (new)	Providing transparency regarding which technologies are used for which purpose helps employees avoid technostress. Joint guidelines from employee representatives and management increase acceptance among the entire staff, which can reduce the frequency, duration, and/or intensity of technostressors.	Binding ICT usage guidelines are concluded within the company that clearly defines the goals, purposes, and framework conditions for using ICTs. The guidelines are revised and updated regularly to ensure that they are up to date.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
10	Consciously manage ICT-related change	yes	1	Providing good and structured support with technology-related change processes can reduce the frequency, duration, and/or intensity of technostressors.	The company actively adapts ICTs to changing internal requirements following good change management. Employees are informed early and comprehensively about the reasons and consequences of the change and can efficiently continue using the changing technologies through training.
11	Develop team norms for the use of ICTs	yes	7	Explicitly communicating rules for handling ICTs for team-internal tasks (e.g., preferred communication channels or file storage) can reduce the frequency, duration, and/or intensity of technostressors.	The team develops rules and guidelines for handling ICTs derived from the company-wide guidelines during team-internal workshops. These rules will be explicitly communicated, documented, and passed on to new employees and continually refined in the long term in an interactive process, allowing quick adaptions. This includes, for example, the definition of rules on which communication tool should be used for which purpose.
12	Establish reachability management	no	2	Creating a common understanding of when, why, and how employees are available for work-related communication can reduce the frequency, duration, and/or intensity of technostressors.	The company defines clear reachability rules, which specify under what conditions and when ICTs are used. These rules are agreed upon together in collective agreements (where there is employee representation). Reachability rules are considered when selecting suitable technologies, for example, to enable the selection of unavailable times.
Enabling Changes to Individuals					
13	Train managers to successfully lead in the digital working world	yes	12	Having digitalization-friendly, inspiring, and employee-oriented leadership can build a trusting and supportive relationship between managers and team members, thus can	The company prepares managers for digitalization challenges in workshops by jointly developing key aspects of digital employee management. For example, this includes supporting employees by making time and other resources available to facilitate effective self- and time management.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
				reduce the frequency, duration, and/or intensity of technostressors.	
14	Train managers for leading distributed team members	no	1	Having good skills in coordinating distributed teams among managers can reduce the frequency, duration, and/or intensity of technostressors.	The company offers workshops for managers to develop important aspects of leading distributed teams and train in the effective coordination and organization of tasks with ICTs.
15	Provide role models with technological changes	yes	6	Showing role models in the healthy use of ICTs and effective support of employees in the event of changes can reduce the frequency, duration, and/or intensity of technostressors.	The company offers workshops for managers to train the healthy use of ICTs and an appropriate way of dealing with change processes. In this way, managers exemplify the use of the newly introduced technologies and serve as role models (e.g., regarding reachability expectations), and support employees in dealing with change.
16	Train mentors for digital topics	yes	5	Providing a personal mentor, who assists employees with technical questions, can reduce the frequency, duration, and/or intensity of technostressors	Employees can request a mentor as a trusted contact person for questions on digital and technical issues. The mentor regularly provides tips and tricks for using ICTs. The inhibition threshold to ask questions is lowered.
17	Train effective self-management and time management	no	10	Practicing good self and time management skills can reduce the frequency, duration, and/or intensity of technostressors.	The company offers voluntary training courses that introduce important aspects of self-management and time management regarding their digital working style. This training includes integrating short breaks into the daily work routine to prevent fatigue and a drop in performance. It enables employees to use ICTs independently, efficiently, and in a beneficial way to their health.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
Secondary Technostress Prevention Measures					
Enabling Changes to Technology					
18	Provide supportive ICTs	no	7	Providing ICTs that support employees in their technostress response, especially in adopting new work routines as coping measures.	Employees can access ICTs with functions that can support them in dealing with technostressors (i.e., changing their technostress response). These include, for example, reminders of breaks, exercise, or important tasks.
Enabling Changes to Organizational Structures and Routines					
19	Provide ICT support	yes	12	Providing competent, fast, and empathetic support for technical questions and problems that allows employees to change their technostress response.	The company sets up a helpdesk to provide employees with fast and competent support for technical questions or problems using ICTs. The helpdesk is trained in the avoidance of technostress and, to purely first-level support, can also respond to requests from overburdened ICT users so that they feel they are taken seriously. All employees know that they can get help from the helpdesk without reproach.
Enabling Changes to Individuals					
20	Train monotasking	no	3	Offering training to focus on only one task at a time helps employees to change their technostress response.	The company offers voluntary training courses that inform employees about the advantages of monotasking – that is, focusing on only one task at a time –, teach approaches to efficient work design, and accompany employees' testing of these approaches in everyday work.
21	Train technostress coping competencies	no	- (new)	Providing technostress coping training help employees to change their technostress response.	The company offers voluntary technostress coping training to their employees that enables them to reduce or eliminate strain caused by technostress. These measures include, for example, the conscious use of ICTs or the avoidance of stressful ICT characteristics.

No.	Technostress Prevention Measure	Inhi-bition?	#	Inhibiting Effect	Description
22	Offer platforms to exchange experience on ICT use	yes	5	Offering sharing formats that enable employees to exchange information on how to use ICTs help employees to change their technostress response by strengthening community sense.	The company establishes forums (preferably in person or as a hybrid format), through which employees can exchange experiences and best practices in dealing with ICTs. Experts moderate these platforms to facilitate joint learning.
23	Provide ICT training	yes	14	Providing training in in-depth technical skills and strengthening media competence helps employees to change their technostress response.	The company offers voluntary training courses that teach employees advanced skills in the use of ICTs. During several pieces of training, employees learn how to use ICTs and practice the transfer in their daily work. These courses are offered especially when new technologies are introduced. Company-wide regulations ensure that every employee is entitled to this training.
24	Foster sensitization and self-reflection regarding technostress	yes	11	Supporting awareness of the causes, effects, and outcomes of technostress and one's working methods helps employees to change their technostress response.	The company offers voluntary training courses that sensitize employees to the dangers of technostress and teach them a toolbox of targeted strategies that help avoid technostress. Exemplary tools include introspection and self-reflection strategies to identify pitfalls of digital work and adapt their way of working.

Table 10: Technostress Prevention Measures

The seven technostress inhibitor articles (see Appendix C.2 for details) each suggested two to seven technostress prevention measures with some overlap among the articles. Overall, twelve prevention measures mainly result from technostress inhibition literature. An additional eight measures result from the remaining articles we reviewed during Phase 0. Finally, four measures are self-developed during our research process bases on experts' feedback. Examples for measures that result, among others, from a technostress inhibition article by Tarafdar et al. (2015) is measure 19 *provide ICT support* or measure 23 *provide ICT training*. An example for

measures that resulted from remaining literature besides technostress inhibition literature, is measure 2, *adapt a stress-sensitive digital workplace design*. Measure 2 results from prevention measure candidates from Arnetz (1996) and M.-S. Lee et al. (2015), who do not refer to technostress inhibition but still provide valuable insights for the development of technostress prevention measures. The column "#" indicates how many times the technostress prevention measure was mentioned in the literature; "-" indicates that the technostress prevention measure was self-developed. The four self-developed measures are measure 1, *focus the ICT landscape*, measure 5 *use gamification*, measure 10 *agree on binding ICT usage guidelines*, and measure 21 *train technostress coping competencies.* While measures 1, 5, and 10 were developed during the workshops in Phase 0, measure 21 was added based on experts' suggestions in Phase 1 of the Delphi study.

Measure 1 refers to the situation of having several redundant systems for the same task (e.g., video conferencing) and information distributed in the organization. The measure aims at reducing the number of systems to a reasonable level and especially involves employees in selecting appropriate systems and ICTs for the given task (e.g., to also offer room for practices like "bring your own device" if this simplifies the process and collaboration). Measure 5 *use gamification* targets the ICT design by including game elements, for example, levels, points, rewards, or badges. ICTs might also react with humor in certain situations. In this way, users are introduced to ICTs through playful behavior. It is important to note that through the Delphi study, we found that participation in such games should be voluntary to avoid (perceived) performance monitoring. Measure 10 *agree on binding ICT usage guidelines* goes in a similar direction as measure 1 but emphasizes the importance of transparency on which ICT is used for which purpose and under what conditions. Measure 21 *train technostress coping competencies* is also highly relevant in the Theory of Preventive Stress Management and separates the constructs of coping from preventive technostress measures (J. C. Quick et al., 1997). Sufficient coping skills are highly important to effectively deal with technostress (Salo et al., 2020; M. Schmidt et al., 2021; Weinert et al., 2020). The preventive measure trains employees' individual technostress coping behavior being part of their technostress response. Coping includes, for example, positive reappraisal, changing the perception of an IT event, or seeking help from colleagues (Beaudry & Pinsonneault, 2005, 2010).

In comparison to the technostress prevention measures synthesized from literature during phase 0, we merged the two technostress prevention measure candidates *foster sensitization regarding technostress* and *foster self-reflection regarding technostress* into *foster sensitization and self-*

reflection regarding technostress based on experts' input during the Delphi study (measure 24), and also added a new measure 21, as mentioned above. Besides these apparent changes to the list of technostress prevention measures, the experts' qualitative feedback in the Delphi study's first phase suggested changes concerning the configurations of single technostress prevention measures. One expert, for example, pointed to the importance that, "especially for inexperienced employees with an IT problem, the IT helpdesk [measure 19, *provide ICT support*; note from the authors] staff should convey a feeling of trust and respect". Many of these suggestions are reflected in the descriptions of the measures. In addition, multiple experts stressed that organizational offers suggested by measures 17 (*train effective self-management and time management*) and 24 (*foster sensitization and self-reflection regarding technostress*) should not be mandatory, as that might even increase employees' stress.

In addition, various experts emphasized the relevance of a diverse portfolio of measures. Although measures targeting individual-level change are important, these measures bear the risk of outsourcing the responsibility for technostress prevention from the organization to the individual. Therefore, the complementary implementation of organizational and technical changes is essential. The 24 technostress prevention measures give a comprehensive overview of available measures in organizational settings and indicate the diversity of technostress prevention opportunities. The list of technostress prevention measures is structured along with the differentiation into primary and secondary prevention and the distinction between measures enabling changes to technologies, organizations, or individuals. The overview of references referring to the measures is presented in Appendix C.2.

Characterization of Technostress Prevention Measures

To better structure and compare the different types of technostress prevention measures, experts characterized them on a set of characteristics during the Delphi study. Each technostress prevention measure's complete characterization is presented in Appendix C.4. The first characteristic (*entity of change*) relates to the entity affected by the technostress prevention measure and comprises the technological, organizational, and individual levels (Murphy & Sauter, 2004). This differentiation stems from Murphy and Sauter's (2004) effort to structure interventions that avoid negative influences on worker health and safety. Measures at the technological level concern the implementation and use of well-designed ICTs that serve their purpose. At the organizational level, measures focus on changing organizational structures, processes, and guidelines (e.g., code of conduct and operating instructions). Lastly, changes on

the individual level comprise technostress prevention measures that create a change in the individual, for example, their behavior. The manifestations of this characteristic are distributed relatively evenly across the 24 measures. The subheadings in Table 10 structure the classification (e.g., measures underneath the subheading "Enabling Changes to Individuals" refer to measures that affect the individual level). Six of the 24 measures address the technological level (e.g., measure 3, *apply human-centered release management*), eight address the organizational level (e.g., measure 12, *establish reachability management*), and ten address the individual level of prevention (e.g., measure 17, *train effective self-management and time management*). Technostress prevention measures on all three levels (technological, organizational, individual) can act as primary or secondary prevention (Murphy & Sauter, 2004; Pirkkalainen et al., 2019; Salo et al., 2017; Weinert et al., 2020). However, the characterization shows very different frequencies of the three levels when comparing the two types of prevention. For primary prevention, the technological level, the organizational level, and the individual level are addressed by an about even number of primary prevention measures (5, 7, and 5 respectively). In contrast, secondary technostress prevention measures primarily address the individual (1, 1, and 5 measures for the technological, organizational, and individual levels, respectively).

Primary technostress prevention measures on the technological level alter the technological environment in such a way that employees experience fewer technology environmental conditions perceived as demanding. Complementary, secondary technostress prevention measures on the technological level refer to measures that aim at providing employees with technological resources to improve their response to technostress (e.g., helping employees by reminding them to take breaks). Similar accounts for primary and secondary prevention measures that target the organizational environment. While individual-level secondary technostress prevention measures mainly address the techno-stressed individual's internal factors (e.g., knowledge, skills, experience), individual-level primary technostress prevention measures primarily target a change of other individuals' behaviors, thus, shaping the social environment.

Target group and *organization size* concern the applicability of the measure for specific people and organizations. On the characteristic of the target group, we observe no fundamental differences between primary and secondary technostress prevention. In terms of the appropriate organization size, nine measures are assessed to be suitable for organizations with as few as ten employees, 13 measures for at least 50 employees, and two measures require at least 250

employees to be conducted effectively. While most measures (21) are seen as suitable to all employees, three are relevant to management only. Interestingly, most primary technostress prevention measures (13/17, ~76%) are deemed applicable only for organizations with at least 50 employees. With secondary prevention, five of seven measures (~71%) are already applicable with as few as ten employees. This indicates that the build-up of employee resources to better react to technostressors (i.e., secondary prevention) is often already feasible with only a few individuals. In contrast, measures initiating large-scale technological and organizational changes require more advanced organizational structures and larger organizations.

Lastly, the characteristics of *implementation duration*, *time from implementation until effect realization*, and *effect duration* take a time perspective. The results suggest that half of the measures can be implemented and brought to operational use in less than one year (e.g., measure 16, *train mentors for digital topics*). In contrast, eleven measures require 1-3 years, and one measure even three years (measure 11, *Develop team norms for the use of ICTs*). These numbers indicate that the initial effort for many measures is seen as relatively low, which is important for reducing the barrier to successful prevention. Similarly, the time required until the effect of the respective measure becomes apparent in operational business is estimated as less than half a year for ten measures (e.g., measure 21, *train technostress coping competencies*), up to one year for 13 measures, and more than one year for only one measure (measure 6, *foster a cooperative culture*). The effect of six technostress prevention measures is characterized to last less than one year, while 18 measures show a positive effect between one to three years (e.g., measure 1, *focus the ICT landscape*). Regarding primary vs. secondary technostress prevention measures, a clear tendency can be observed. The *average implementation duration* and *time until effect realization* are longer for primary than secondary technostress prevention. However, the *effect duration* for primary prevention was assessed to last 1-3 years for 14 of the 17 measures (~82%), while of the secondary technostress prevention measures, only four of seven measures (~57%) last 1-3 years and the rest less than one year.

Next, we asked the experts for a relevance assessment on which primary technostress prevention measures are expected to target which technostressor. For each technostressor, we identify two to six measures that the experts assessed as the most relevant. The resulting scores serve as a basis for confirmative quantitative statistical analyses on the relevance of different technostress prevention measures on the set of technostressors. Table 11 presents these relations and graphically displays the average relevance (scale from 0 to 6) of the measures for the respective technostressor for all primary technostress prevention measures. The measures are

sorted according to their accumulated relevance score. Appendix C.5 presents the complete list of numerical relevance ratings and the number of experts who assessed the measure as highly relevant.

No.	Primary Technostress Prevention Measure	Complexity	Insecurity	Interruptions	Invasion	Invasion of Privacy	Overload	Role Ambiguity	Uncertainty	Unreliability
4	Apply human-centered ICT design	●	○	○	○	◕	○	●	○	●
13	Train managers to successfully lead in the digital working world	○	●	○	●	◕	○	○	◑	○
1	Focus on the ICT landscape	●	○	○	○	○	○	●	○	◕
17	Train effective self-management and time management	○	○	◕	●	○	◕	○	○	○
11	Develop team norms for the use of ICTs	○	○	◕	●	◕	○	○	○	○
12	Establish reachability management	○	○	●	●	○	◑	○	○	○
6	Foster a cooperative culture	○	◑	○	◕	◕	○	○	○	○
15	Provide role models with technological changes	●	●	○	○	○	○	○	○	○
16	Train mentors for digital topics	○	●	○	○	○	○	◑	◑	○
5	Use gamification	○	○	○	○	○	○	○	●	○
2	Adapt a stress-sensitive digital workplace design	○	○	◑	○	○	○	○	○	◔
3	Apply human-centered release management	◕	○	○	○	○	○	○	○	○
8	Introduce an employee data security concept	○	○	○	○	◕	○	○	○	○
9	Agree on binding ICT usage guidelines	○	○	○	○	◕	○	○	○	○
10	Consciously manage ICT-related change	◑	○	○	○	○	○	○	○	○

No.	Primary Technostress Prevention Measure	Complexity	Insecurity	Interruptions	Invasion	Invasion of Privacy	Overload	Role Ambiguity	Uncertainty	Unreliability
7	Develop a mission statement for digital collaboration	○	○	○	○	○	○	○	○	○
14	Train managers for leading distributed team members	○	○	○	○	○	○	○	○	○

○	◔	◑	◕	●
Not specifically relevant (relevance < 4.0)	Somewhat relevant (4.0 ≤ relevance < 4.5)	Relevant (4.5 ≤ relevance < 5.0)	Very relevant (5.0 ≤ relevance < 5.5)	Highly relevant (relevance ≥ 5.5)

Table 11: Relevance of Primary Prevention Measures to Reduce Technostressors

When assessing the relations, no two technostressors share the same set of relevant technostress prevention measures. However, some patterns exist. For example, two technostress prevention measures can potentially help prevent complexity, unreliability, and role ambiguity. Both prevention measures (numbers 4 and 1) target the technological environment. When they reduce the complexity and unreliability of the technology, the need for employees to acquire new skills for working with complex and unreliable technology (and, hence, role ambiguity) are reduced. Similarly, interruptions and invasions share multiple prevention measures. Accordingly, these pairs of technostressors can be addressed through similar prevention measures.

Each technostress prevention measure is selected as a technostressor's most relevant measure between zero to four times. Interestingly, two primary technostress prevention measures (measure 14, *train managers for leading distributed team members*, and measure 7, *develop a mission statement for digital collaboration*) are not selected to be among the most relevant for any technostressor. This result does not mean that the measures are generally not relevant for preventing technostress. However, it does indicate that industry experts do not expect them to be among the most relevant measures for addressing one of the nine considered technostressors. In contrast, two technostress prevention measures (measure 4, *apply human-centered ICT design*, and measure 13, *train managers to successfully lead in the digital working world*) are assessed as very or highly relevant to four different technostressors. This finding indicates that the two are rather general technostress prevention measures that are suitable for multiple technostressors. In that, measure 4 relates to changing the technological environmental conditions and measure 13 relates to the prominent role of leadership in preventive stress management (i.e., principle 2 of (techno)stress management). Other measures (e.g., measure 9,

agree on binding ICT usage guidelines, and measure 10, *consciously manage ICT-related change*) are only relevant to one technostressor. These measures are expected to be specialized in addressing a particular technostressor.

4.1.5 Research Propositions

Based on our results, we provide five propositions on preventive technostress management. The propositions are an abstraction of the results presented above. We see propositions as proposed relationships between constructs on the theoretical plane as compared to hypotheses on relationships between variables on the empirical plane (Bhattacherjee, 2012). The propositions are theoretical in the sense of relating to the understanding of a theory as relationships among constructs along with arguments substantiating the relationships and a definition of the scope of validity of the relationships (Whetten, 1989). The purpose of the propositions here is to provide statements on potential relationships between technostress prevention constructs that stem from our empirical results and are compatible with existing theory on technostress and preventive stress management. The propositions are tentative and conjectural relationships between constructs; they need further theorizing and , after being transferred to research hypotheses, empirical testing for being fully integrated in theories of technostress. The propositions relate to abstract constructs on the theoretical plane. Hence, they cannot be tested empirically directly. Nevertheless, the propositions can serve as a foundation for developing testable hypotheses in the form of relationships between variables on the empirical plane (Bhattacherjee, 2012). The empirical test of hypotheses derived from the propositions is an indirect test of the propositions that will allow to reflect on their truth and usefulness. Once validated through the corresponding empirical test of related hypotheses, the propositions may serve as basis for designing preventive technostress management tools, methods, and programs.

For all following propositions, the scope is technostress in a work context with the organization as the entity that can prevent technostress among its employees. The arguments substantiating the proposed relationships derive from the contextualization of the Theory of Preventive Stress Management to technostress and the results of the literature analysis and the Delphi study.

Proposition 1: *The five principles of preventive stress management also apply to technostress.*

J. C. Quick and Quick (1979) intensively discuss work stress and its prevention. Given their publication before the widespread dissemination of digital technologies to work places, technology is not explicitly in focus. J. C. Quick et al. (1997) however do shortly discuss the

role of early production technologies and a mismatch between people, task, technology, and structure as factors to consider in work stress research. Therein, the principles of preventive stress management are expected to apply to technostress, as technostress is a specific form of general stress. As such, the proposition is straightforward and in line with existing theory. Nevertheless, we suggest that stating it explicitly is important to direct the attention of technostress researchers towards (principle 1) the interdependence of individual and organizational health, (principle 2) the responsibility of leaders for individual and organizational health, (principle 3) the ability to prevent (or inhibit) individual and organizational stress, and (principle 5) the need for constant adaptation of preventive technostress management to keep up with ever-changing and dynamic organizations (J. C. Quick et al., 1997). Additional empirical evidence for the relevance of principles 2 and 3 can be found in the presence of prevention measures solely relevant to leadership (measures 13-15, principle 2), as well as the overall positive Delphi expert assessment of many prevention measures regarding their effectiveness in preventing technostress (principle 3). Principle 4 refers to the individuality of organizations and persons in their reaction to technostress (J. C. Quick et al., 1997). We do not see a need to direct attention to this principle as it is already front and center in technostress research (Beaudry & Pinsonneault, 2005; J. V. Chen et al., 2019; Pirkkalainen et al., 2019; e.g., Salo et al., 2020).

Proposition 2: *Technostress prevention measures address the technology, the organization, and/or the individual. Secondary technostress prevention measures focus primarily on the individuals.*

The differentiation of addressing technology, organizations, and/or individuals in prevention derives from literature (Murphy & Sauter, 2004; J. C. Quick et al., 1997). Historically, the focus was mainly on distinguishing individuals and organizations (J. C. Quick et al., 1997). However, with the digitalization of work, the specific attention to technologies as a central component of work stress has emerged (e.g., Ayyagari et al., 2011; Ragu-Nathan et al., 2008; Tarafdar et al., 2019). This general differentiation is empirically supported by the developed set of technostress prevention measures, given that it spans all three categories. The focus of secondary prevention on individuals is primarily induced from the characterization of the technostress prevention measures. Five of the seven (71%) secondary prevention measures concern the individual level. Further, this insight integrates well with existing stress prevention theory. Secondary technostress prevention targets individuals' technostress responses, i.e., physiological, psychological, and behavioral responses of individuals experiencing technostress (J. C. Quick

et al., 1997). The behavioral response might be influenced by the technology or organization. However, physiological and psychological response are happening within the individual – hence the focus of respective prevention measures on individuals (LaMontagne et al., 2007; Salo et al., 2017). Omissions in proposition 2 are also noteworthy: The proposition does not refer to addressing the environment, customers, the employees' family or the like. Thus, the proposition suggests a clear focus for identifying and designing further technostress prevention measures.

Proposition 3: *Primary prevention measures differ with respect to the number of technostressors they are relevant for.*

Focusing on the relationship between technostressors and primary technostress prevention measures, we found patterns regarding the relevance of primary technostress prevention measures to reduce the frequency, duration, or/and intensity of technostressors. Our results indicate that not every measure addresses all technostressors equally. Some measures are relevant for one or a few specific technostressors, while other measures target a broader set of technostressors. For example, measure 8 (Introduce an employee data security concept) is explicitly concerned with increasing data security and reducing related risks. The measure is highly focused on one specific downside of digitalized workplaces and, as a result, targets only one technostressor: Invasion of privacy. In contrast, measure 13 (Train managers to successfully lead in the digital working world) addresses the very general topic of digital leadership. Strong digital leaders can help improve technostress stemming from all types of technostressors by identifying sources of technostress in time. The measure thus affects several technostressors (i.e., insecurity, invasion, invasion of privacy, and uncertainty). Table 11 gives the first indication of this matching based on the Delphi study's expert assessment, which requires future empirical research to verify. While existing research has not yet systematically matched the full list of technostressors with the list of technostress prevention measures, few studies have investigated the effectiveness of some subset of technostress prevention measures for certain technostressors (e.g. Galluch et al., 2015; M. Schmidt et al., 2021; Valta et al., 2021). Their work supports the proposition that technostress prevention measures support different numbers of technostressors. For example, Valta et al. (2021) demonstrate social support systems and contact persons as measures addressing many technostressors. In contrast, the reduction of e-mail traffic is shown to be very useful only for two of their technostressors. In conclusion, we see a need for future research to go beyond our Delphi study's relevance assessment and empirically establish the effectiveness of the different measures. Supporting

technostress prevention in practice will require developing a body of knowledge on how to best select and implement a portfolio of technostress prevention measures which addresses the most important technostressors in a given organization.

Proposition 4: *Technostressors differ with respect to whether they are addressable through only a few or many primary technostress prevention measures.*

Considering technostressors as the baseline (columns in Table 11), a few observations emerge from the empirical results in this subchapter. Not all technostressors share the same number and relevance levels of technostress prevention measures through which they can be targeted. Consequently, some technostressors might be more difficult to address, requiring highly specialized measures for prevention. Others, however, exhibit a larger set of measures as potential prevention tools. For example, invasion is indicated to be addressable through several different measures. The technostressor addresses a vague feeling of having to be connected and there are many ways to change this perception. Unreliability, on the other hand, is only matched with three measures. As unreliability describes technostress from technical failure, the options for prevention are more limited: improve technical reliability or improve coping with failures. Complementing our observations, Valta et al. (2021) has highlighted results that support this hypotheses. In their study, for example, overload is demonstrated to be addressable by multiple technostress prevention measures in their sample, while cyberbullying is only addressed by one. As with proposition 3, we deem it important to point to this multifaceted interplay of primary technostress prevention measures and technostressors to spur future research in the direction of providing knowledge on managing a portfolio of technostress prevention measures.

Proposition 5: *Compared to secondary prevention, primary technostress prevention measures represent a longer-term approach with a longer effect duration, but also require higher initial efforts.*

Deep-diving into the characteristics of primary and secondary prevention measures in Appendix C.4, we identified that primary measures tend to require higher average initial efforts for implementation and effect realization than secondary prevention measures. While for primary prevention only six out of seventeen (35%) technostress prevention measures require less than one year for implementation, six out of seven (86%) secondary technostress prevention measures were characterized with the shortest implementation time category. Simultaneously, however, the experts indicated that primary technostress prevention measures yield longer-term positive effects. This leads to the proposition that primary technostress

prevention is more focused on a long-term approach to preventing technostress, while secondary technostress prevention measures on average present a short- and mid-term solution to preventing technostress. Existing literature has not yet analyzed the differences between effect and implementation duration when comparing primary and secondary prevention. However, the nature of both prevention types offers some arguments supporting this proposition. Secondary prevention measures mostly address individuals and their response to technostressors, including their skills, competencies and experiences (Salo et al., 2017). Trainings and workshops that improve an individual's coping or IT skills can be conducted within a matter of hours or days thus leading to a low implementation and effect duration effort. On the downside, high employee turnover rates, particularly in IT professionals, lead to a frequent loss of knowledge and skills gained from secondary technostress prevention measures and reduce the effect duration period in this prevention type (X. Wang et al., 2022). Primary prevention measures on the other side often target the technological and organizational environment (J. C. Quick et al., 1997; Salo et al., 2017). Therein, changes stemming from prevention measures often affect overarching organizational and technological structures comprising many people and entities. While this makes their implementation more complex and time-consuming, it also reduces the dependency on individuals, thus increasing the effect duration period.

4.1.6 Discussion

Reducing the adverse outcomes of technostress is essential. In an ideal world, organizations invest in addressing technostress at an early level and throughout the process (Brivio et al., 2018). To sustainably reduce technostress, organizations need to implement ex-ante measures to prevent future stressful situations caused by technostressors, and they need to support their employees in responding to technostress. To drive knowledge on prevention in the technostress field and assist practitioners in implementing successful technostress prevention management, we bring together different research strands of technostress inhibition and stress management and enrich the combined perspective empirically. With our research, we follow Tarafdar et al.'s (2019) call for (1) a more thorough investigation of how altering technological aspects in an organizational environment can prevent technostress and (2) applying a methodological approach in technostress research that complements the current focus of technostress research on surveys.

Contribution and Theoretical Implications

The subchapter contributes to research in four ways:

(1) Embedding technostress inhibitors in the larger context of preventive technostress management
(2) Providing a structured overview of 24 technostress prevention measures
(3) Characterizing of the 24 technostress prevention measures in terms of their basic approach to preventive technostress management, their applicability in practice, and their relevance in targeting technostressors.
(4) Formulating propositions on preventive technostress management

First, we embed existing knowledge on technostress inhibition in the larger context of preventive technostress management by bringing together theory on technostress inhibitors (e.g., Ragu-Nathan et al., 2008; Sarabadani, 2018) with the three types of stress prevention (primary, secondary, tertiary) from the Theory of Preventive Stress Management. The research strand of technostress inhibition theorizes inhibitors to either (1) act as antecedents to technostressors (Jena, 2015; Tarafdar et al., 2015; Tarafdar et al., 2011), moderate the relationship between technostressor and outcomes (Ragu-Nathan et al., 2008), or decrease adverse outcomes directly (Jena, 2015; Ragu-Nathan et al., 2008; Tarafdar et al., 2011). We synthesize this existing knowledge and combine it with insights of the Theory of Preventive Stress Management which are very similarly located in the general stress process as the three theorizations of technostress inhibition. For example, Tarafdar et al. (2015) integrates technostress inhibitors as antecedents to technostressors, including the three inhibitors: “Facilitate technical literacy”, “provide technical support”, and “facilitate technology involvement”. While Ragu-Nathan et al. (2008) and Fuglseth and Sørebø (2014) mention the same three technostress inhibitors, the integration into the technostress process differs. Based on our definition of primary and secondary technostress dimension, we use these insights to summarize and structure applicable technostress prevention measures on the same level of detail in their role of the technostress process. Based on the insights of the different research strands of technostress inhibition and preventive stress management, we develop a conceptual model of preventive technostress management detailing the target points of the three types of technostress prevention. Hereby, we provide five guiding principles of technostress management. These are derived from the Theory of Preventive Stress Management and are new to the technostress literature.

Second, we provide a structured list of 24 actionable technostress prevention measures which consists of a synthesis of inhibitor literature (twelve technostress prevention measures), a literature-based expansion of eight further technostress prevention measures mentioned in related technostress literature, and an empirical expansion of four new technostress prevention measures. Therefore, while 20 of the 24 technostress prevention measures presented in this subchapter have in some form been mentioned in technostress literature (e.g., *provide ICT training* or *provide supportive ICTs*) (e.g. Adam et al., 2017; Pfaffinger et al., 2020), their domain varies between technostress inhibition (e.g., Fuglseth & Sørebø, 2014; Tarafdar et al., 2015), mitigation (e.g., Day et al., 2012; Hung et al., 2015), coping (D'Arcy et al., 2014; e.g., Pirkkalainen et al., 2019), or other related constructs (e.g., Benlian, 2020; Richter & Richter, 2020). Regarding the research strand of technostress inhibition, the inhibitors named by, among others, Tarafdar et al. (2015), Ragu-Nathan et al. (2008), or Fuglseth and Sørebø (2014) were used as inputs for, among others, the prevention measures 3 *apply human-centered release management* (primary prevention), measure 19 *provide ICT support* (secondary prevention), and measure 23 *provide ICT training* (secondary prevention). Beyond the named technostress inhibitors, the articles mention further prevention measure candidates, that went into the description of our prevention measures. For example, next to the three above mentioned technostress inhibitors, Fuglseth and Sørebø (2014) state: "However, the study also indicates that managers should actively encourage employees to try out new ICT, and reward employees for using new ICT" and "In addition, managers should emphasize teamwork and encourage ICT knowledge sharing". These insights went, among others, into the prevention measures 13 *train managers to successfully lead in the digital working world*, measure 15 *provide role models with technological changes*, and measure 22 *offer platforms to exchange experience on ICT use*. This example illustrates that our results go beyond existing literature on technostress inhibitors and related studies. We expand on prior literature by intensively analyzing existing studies and collecting all possible content as prevention measure candidates to then synthesize them by clustering them on the same level of detail and discussing them with experts. The engagement with the experts results in adding further technostress prevention measures beyond literature.

The first two contributions lead to the following implications for research: Researchers working on analyzing or designing technostress inhibitors can use the prevention framing and approach literature on general stress prevention to obtain further theoretical grounding for their technostress research. Further, they can use our set and structure of technostress prevention

measures as a broad overview of measures in the otherwise fragmented literature. Finally, researchers working on stress prevention in other domains besides technostress might consider our set of technostress prevention measures as inspiration for identifying similar prevention measures in other specific stress contexts or in abstracting them from technostress to general stress prevention research.

Moving to the third contribution, we structure and characterize all 24 measures in terms of their basic approach to technostress prevention (i.e., primary and secondary technostress prevention as well as the entity affected: technology, organization, or individual), their applicability, and their relevance in targeting technostressors (for primary measures). Thereby, we contribute a common starting ground for addressing technostress prevention from an organizational view. Due to their importance for future technostress research, we point out two specific facets of the set of characterized technostress prevention measures: The importance of leaders and the lack of a one-fits-all approach. The importance of leaders has been emphasized for preventive stress management (Macik-Frey et al., 2007; J. C. Quick, 1992). Because of the critical role of leaders, it can be beneficial for organizations to also target primary stress prevention measures to leaders (e.g., executive coaching and peer support) (Hargrove et al. 2011). Arguably, leaders play a similarly important role in technostress prevention as in the prevention of stress in general. Looking at the most relevant primary technostress prevention measures, we find that measure 13, *Train managers to successfully lead in the digital working world* is the second most relevant (Table 11). Further concerning prior findings on primary stress prevention measures in general, the provision of instrumental (e.g., buddies or mentoring programs), informational (e.g., improvement of the flow of information), and emotional (e.g., increasing emotional understanding among employees) support proofed effective as primary preventive interventions (J. C. Quick & Quick, 1984a). In the specific context of technostress, we also identified all types of the mentioned support measures with a specific focus on ICTs: Measure 15, *provide role models with technological changes*, and measure 16, *train mentors for digital topics* (8th and 9th most relevant primary technostress prevention measure), relate to the first category of "instrumental support". Informational support is addressed by the third relevant technostress prevention measure, measure 1, *focus on the ICT landscape* by reducing the complexity and avoiding redundancies of information. Lastly, emotional support is mainly addressed by measure 6, *foster a cooperative culture* (6th most relevant primary technostress prevention measure). While the most relevant primary preventive stress measures can be found in the nine

most relevant primary technostress prevention measures, we additionally found purely ICT-specific measures like the most relevant measure 4, *Apply human-centered ICT design*.

Our efforts in characterizing the different technostress prevention measures in terms of their applicability also help structure the field of preventive technostress management. We offer the possibility to describe measures or groups of measures on a shared set of characteristics. This possibility is important to better compare and classify similar measures in future research. Technostress research can make use of this grouping by not having to assess every measure individually but by being able to assess groups of measures that are similar in their characteristics. We found that primary technostress prevention measures require high initial efforts but yield long-term effects. Therein, primary technostress prevention measures deem a suitable long-term approach for designing workplaces that are technostress free. In contrast, most secondary prevention measures target individuals and require fewer implementation efforts. Thus, they present an opportunity for short- and mid-term prevention of technostress by enabling employees to better react to technostressors in the phase before they have been eliminated permanently. For future research, the implementation and effect duration classification also help design more appropriate studies on testing the actual effectiveness of the different measures. For example, a measure that takes one year to create a positive effect cannot reasonably be assessed in a six-month field study.

Additionally, we provide initial evidence that technostress prevention measures are expected to address different technostressors, and prevention is no one-fits-all mechanism. Hereby, we related the primary technostress prevention measures to nine established technostressors to increase practical applicability and to build the foundation for extensive empirical analyses in future research. Therein, we built on, validated, and extended the few studies that assessed selected prevention measures' potential for specific technostressors (e.g. Galluch et al., 2015; M. Schmidt et al., 2021; Valta et al., 2021). For example, our results confirm and expand the findings of Valta et al. (2021), who investigated seven measures (e.g., ICT training, contact person) to reduce single technostressors. The authors found that, for example, homogenizing the ICT landscape (here: measure 1, *focusing the ICT landscape*) reduces the technostressor *complexity*. This goes along with our results (e.g., measure 1 is highly relevant for complexity). We expanded the results by finding more technostress prevention measures that are expected to be relevant for preventing complexity (e.g., measure 3 *apply human-centered release management*, measure 4 *apply human-centered ICT design*, and measure 10 *consciously manage ICT-related change*). Stemming from the descriptive results of the expert panel, our

results serve as the first foundation for relevance. Scholars in the field can build on these results and further theorize on the relationship between individual technostress prevention measures (or sets of such measures with similar characteristics) on specific technostressors.

Finally, we contribute by abstracting our theoretical and empirical results to five propositions on preventive technostress management. These are contributions to technostress research, not to the general Theory of Preventive Stress Management. Combining our results with other such contextualizations of specific forms of stress, it might eventually become possible to consolidate the specific findings into a more general context-contingent theory of preventive stress management (Hong et al., 2014). Our five propositions are grounded in theorizing and empirical evidence. We call for future research engaging with these propositions to refute, refine, or validate them. The guiding principles of preventive technostress management and proposition 1 provide a new framing and a new lens to researching technostress at work. Future technostress research should further build on stress prevention theory to advance our knowledge on organizational health, the responsibility of leaders for health, and the constant management and adaptation of a portfolio of technostress prevention measures.

Practical Implications

Organizations have a moral, legal, and economic obligation to address work-related technostress among employees. Moral in the sense of having the responsibility to offer a workplace that is safe and healthy. Legal in the sense that countries like Germany have established laws on an organization’s duty to protect employees' physical and psychological well-being. Economic in the sense that technostress can impair an individual’s health and work performance and negatively impact an organization’s performance (Tarafdar et al., 2015). As adverse outcomes from technostress are not acute events but develop over time, it is important to prevent technostress throughout the process, rather than only reacting after adverse outcomes arise. This indicates a need to support organizations in their prevention efforts by providing actionable fine-grained knowledge on preventive technostress management and measures to implement.

Our research demonstrates the diversity of available prevention measures and, thus, supports organizations in finding a set of measures applicable to their specific setting. Especially for organizations new to technostress prevention, our set of measures offers an information source to understand what different aspects prevention can comprise. Most measures are primary technostress prevention measures. This is noteworthy because secondary prevention is

prevalent in job-related stress prevention practice, even though primary prevention is deemed more effective as it tackles stress at its source (LaMontagne et al., 2007). By offering a rich set of primary technostress prevention measures, we support organizations in establishing a comprehensive approach to preventive technostress management.

In terms of characterization, this subchapter shows that most measures are available for organizations of all sizes. However, the measures differ strongly in the technostressors they address, their implementation costs, or their required expert knowledge. Further, most measures require relatively little time until implementation and effect realization. These are encouraging news for practice that might take away some of the burdens when starting with technostress prevention. The characterization of measures also serves as decision support for organizations. When choosing measures, one can easily filter measures by the relevant criteria (e.g., size or entity of change) to be presented with a set of appropriate measures.

The results on the difference in relevance of single technostress prevention measures and specific technostressors have substantial implications for practice. The relevance of technostress prevention measures is expected to be significantly impacted by the technostressor responsible for the technostress. Hence, as the first step to technostress prevention, organizations must identify the critical technostressors within their workforce. Only once an organization knows which technostressors cause technostress to what extent they can effectively select prevention measures. Different measures or a portfolio of prevention measures might be appropriate depending on whether one or multiple technostressors are prevalent. Especially if resources are scarce (typically), it is crucial to prioritize the most severe technostressors concerning prevention.

Limitations

Like any research, this research is subject to limitations. First, our results are based on the expertise of a limited number of 13 panelists and, before the Delphi study, a structured literature review and 17 experts in focus groups. We are convinced that our panel is diverse because panelists stem from different organizations of different industries. Still, we can make no formal claim about the panel's representativeness. Even though our Delphi study panel's structure and size fit our research purpose, the measures' relevance (Table 11) should be interpreted only as a rough first estimate. These relevance statements need to be evaluated in more extensive quantitative empirical research in the future to make definitive, generalizable claims. The effectiveness of a technostress prevention measure may highly depend on individual and

organizational differences and characteristics (principle 5). For example, demographics, professional experience, or computer self-efficacy potentially affect how strongly people experience technostress and how effective a prevention measure is. To address this, future research should also assess the significance of such confounding variables, similar to existing studies such as Tams et al.'s (2018) work.

Second, we examined the assumed effects of primary technostress prevention measures on nine technostressors. While the selection comprises the most frequently studied technostressors, the literature holds further technostressors (Maier et al., 2012). Also, since the research field is currently rapidly advancing, new technostressors were proposed in the meantime. One example is T. Fischer et al. (2021), who developed ten technostressor categories, including new constructs like social environment or technical support. Consequently, some newer technostressors found no consideration in the Delphi study. Further technostressors could be included in future works.

Third, we did not narrow the organizational scope to industries or company sizes. We kept the scope broad because this overview of technostress prevention is aimed to be relevant for all types of organizations. However, some of our results might depend on the respective industry, especially concerning primary technostress prevention measures. This should be considered when applying the measures in organizations, and an additional individualization of measures to industries could be required.

Fourth, this subchapter derives work-related technostress prevention measures that enable technological, organizational, and individual changes. On the technological level, the prevention measures are mostly generic in that they generally refer to ICTs. It would be valuable to assess specific ICTs (e.g., e-mail applications or data management software) as a next step. One could also develop additional prevention measures that target any technostress from the respective ICTs or group of ICTs.

Fifth, in this subchapter, we address individual technostress prevention measures. In real-life scenarios, organizations will apply portfolios of such measures. To increase applicability, it would thus be precious to create a) quantification of the effect of different prevention portfolios (including any positive and negative interdependencies) and b) a handbook/ guideline on how to develop and implement such a portfolio in each setting.

Finally, we derive propositions of preventive technostress management, which have an empirical basis. However, they should be transformed to research hypotheses for empirical testing in future research.

Conclusion

Understanding technostress and its adverse outcomes have emerged as popular and important research endeavors. Research has extensively investigated the potential effects of technostress on employees' health and organizational performance (Fuglseth & Sørebø, 2014; Ragu-Nathan et al., 2008; Srivastava et al., 2015; Tarafdar et al., 2015; Tarafdar et al., 2007). This subchapter complements existing research by combining the research strands of technostress inhibition and further related technostress-reducing literature with preventive stress management. Thereby, we focus on addressing the ex-ante prevention of technostress from an organizational perspective. The results provide guiding principles and propositions for preventive technostress management. For digital innovation for sustainability, this subchapter highlights the importance of creating healthy internal environments. The set of prevention measures and their specifications provide practitioners with tools to reduce technostress levels in order to best leverage digital technologies for digital innovation for sustainability.

4.2 Assessing the Use of Digital Innovation for Sustainable Customer Behavior

Subchapter 4.1 focuses on internal environments for digital innovation for sustainability. Organizations, however, do not function as isolated systems but they are dependent on the external competitive environment they operate in (Kohli & Melville, 2019). The actions of competitors, customers, suppliers, or policy makers strongly impact how organizations innovate digitally for sustainability. One prominent example for the role of customers is the recycling of plastic waste. The poor disposal and recycling of plastic waste contributes significantly to waste generation and environmental pollution. By 2050, up to 12 billion tons of plastic waste are expected to end up in landfills or the natural environment if no countermeasures are taken (Geyer et al., 2017). One reason for this is the increasing popularity of takeaway food and beverages. In Germany alone, approximately 28,000 tons of waste are generated each year through the consumption of 2.8 billion hot beverages in disposable cups. To-go consumption accounts for an estimated 1.2 billion of these (Kauertz et al., 2019). To-go consumption is inevitably associated with significant amounts of waste. However, the use of

disposable containers is accompanied by a number of other problems. For example, the disposable paper cups used for coffee to-go are usually coated with a thin layer of plastic to make them more robust. This results in the cups being very difficult to recycle (Mitchell et al., 2014) and the majority ending up in incinerators (Kauertz et al., 2019; Novoradovskaya et al., 2021).

Sustainable innovations such as reusable systems represent a more environmentally friendly alternative to single-use packaging (Novoradovskaya et al., 2021). They contribute to a reduction in CO_2 emissions and counteract the littering of public spaces (Mitchell et al., 2014). However, looking at the case of Germany, the usage rate of reusable systems has hardly changed for years despite its positive potential for sustainability (Umweltbundesamt, 2021). Usage is far from the German government's target rate of 70% for reusable alternatives (Umweltbundesamt, 2021). To accelerate reusable system usage, policymakers are promoting reusable alternatives through new guidelines and measures. At EU level, a plastic strategy was adopted in 2018 as part of the 'Circular Economy Action Plan' to reduce plastic waste (European Commission, 2018). In 2021, the German government also ruled that all catering businesses must offer a reusable alternative for to-go drinks and meals from 2023 onwards. However, even with these measures undertaken, the usage rates for reusable systems are still falling behind expectations.

The success of to-go reusable systems (TGRS) thus heavily depends on the willingness of customers to use them (Greenwood et al., 2021). The stagnating growth of TGRS usage points to the current lack of successful initiatives motivating people to avoid single-use alternatives (Ertz et al., 2017; Jiang et al., 2020; Novoradovskaya et al., 2021). This yields the question of how to better foster TGRS usage. To support customers in their transition to more sustainable behavior, digital innovations (e.g., artificial intelligence, cloud computing, or big data) have been proven a valuable support tool in various other contexts, such as mobility or e-commerce, for example through digital nudges towards sustainable choices or real-time information on sustainable options (e.g., M. Berger et al., 2022; Gimpel et al., 2022; Zimmermann et al., 2024). Given its potential in other domains, the usage of digital innovations in TGRS companies also deems promising. So far, research has not yet assessed how digital innovations are applied in TGRS companies to drive usage rates.

Against this backdrop, we propose the following research question:

How do companies apply digital innovations to improve the usage rates of reusable systems in the food and beverages to-go sector?

To answer the research question, we first conduct a pre-study to identify the impact factors influencing customers' usage intention and behavior in respect to TGRS, building on the Theory of Planned Behavior (TPB), supplemented by variables from environmental behavior research (Ajzen, 1985). The impact factors identified in the pre-study are then used as a basis to assess how digital innovations are currently being used to positively affect each impact factor to increase TGRS usage rates. To capture real-life TGRS companies and their application of digital innovations, we systematically analyze information on 21 TGRS companies through qualitative coding (Corbin & Strauss, 2008; Wolfswinkel et al., 2013). Yielding 15 applications of digital innovations structured along different impact factors of TGRS behavior, we draw a clear picture of how industry currently leverages digital innovations and contribute to the academic discussion on what is still to be done to reduce waste.

4.2.1 Theoretical Background

To-Go Reusable Systems

Reusable packaging differs from single-use packaging in that it can be used multiple times. According to the German Packaging Act, reusable packaging is defined as "[...] packaging that is designed and intended to be reused several times for the same purpose after use and whose actual return and reuse is made possible by adequate logistics and promoted by suitable incentive systems, usually by a deposit" (Article 3(3) of the Packaging Act, German Ministry of Justice, 2019). According to Greenwood et al. (2021), there are two main categories of reusable systems. First, there are *individual systems* where the container is owned by the customer and is brought in independently for filling. Second, with *return systems*, the reusable container is owned and cleaned by a company and is returned by the customer after use in order to re-introduce it in the reusable system cycle. In the context of this subchapter, return systems, also called pool systems, will be examined. In pool systems, suppliers lend out their reusable containers to restaurants or cafés, who in turn offer their food and beverages as to-go options in the respective containers (Coelho et al., 2020). The participating restaurants pay a fee per use or a flat membership fee to the operator of the pool system.

In general, plenty of studies have investigated pro-environmental behavior and its impact factors (e.g., Bamberg & Möser, 2007; Ertz et al., 2016; Yuriev et al., 2018). The use of TGRS can also be understood as a form of pro-environmental behavior, given its positive environmental impact. Previous studies on TGRS specifically have, for example, analyzed the properties of reusable containers (Greenwood et al., 2021), or investigated the preferences of customers and restaurants with regard to different return options (Jiang et al., 2020). Furthermore, few studies have analyzed the topic of reusable packaging from a behavioral science perspective in order to understand usage behavior patterns and associated challenges (Ertz et al., 2017). On a global level, Greenwood et al. (2021) conducted an online survey in the UK to investigate which types of products and packaging customers want to reuse, dispose, or recycle. Keller et al. (2021) assess the behavioral factors that lead customers to switch from single-use to reusable alternatives. Their results show that emphasizing social norms can be an effective means of triggering a switch to reusable alternatives. In addition, Novoradovskaya et al. (2021) investigate potential predictors of reusable coffee cup use at Australian universities and assess the effects of four intervention strategies. Results indicate that routines and habits, as well as environmental norms, significantly predict reusable cup use. Lastly, Ertz et al. (2017) consider the use of reusable alternatives referring to reusable coffee cups, shopping bags, and drinking bottles. Their study shows that both context and personal motivation have a strong impact on the intention to use reusable alternatives. The above-mentioned studies are important steps in the direction of fostering TGRS use.

Sustainable TGRS Behavior

To better understand and develop mechanisms for fostering pro-environmental behavior in respect to TGRS, identifying the underlying factors impacting such behavior is crucial. On a theoretical plane, the TPB (Ajzen, 1991) is one of the most influential and widely used theories to explain human behavior and builds on the Theory of Reasoned Action (Ajzen, 1985, 1991). A major advantage of the TPB is that a large number of factors that determine complex human behavior can be considered in a comparatively simple theoretical model (Litvine & Wüstenhagen, 2011). Its original variables used to explain usage intention and usage behavior are *subjective norm*, *attitude*, and *perceived behavioral control* (Ajzen, 1985, 1991, 2006).

Table 12 provides a definition of all variables.

Construct	Definition	Source
Environmental norm (also biospheric values)	"a concern with the quality of nature and the environment for its own sake, without a clear link to the welfare of other human beings"	Steg et al., 2014, p. 166
Context	"consumers' perception about favorability of the context" (e.g., availability)	Ertz et al., 2017, p. 337
Subjective norm	"the perceived social pressure to perform or not to perform the behavior"	Ajzen, 1991, p. 188
Attitude	"the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question."	Ajzen, 1991, p. 188
Perceived behavioral control	"the perceived ease or difficulty of performing the behavior"	Ajzen, 1991, p. 188

Table 12: Definition of Variables in the Adapted Theory of Planned Behavior

In recent years, the TPB has been increasingly used to study pro-environmental behavior (Bamberg & Möser, 2007; Klöckner, 2013; Leeuw et al., 2015). It has also already been applied in the specific context of private reusable items (e.g., refillable water bottles and shopping bags) and has proven to be a suitable model for customer behavior in this context (Ertz et al., 2017). Therein, the TPB deems a suitable theoretical lens for assessing impact factors of TGRS usage behavior, which then portray potential levers of digital innovation to improve usage rates. Previous research has demonstrated the importance of *environmental norms* and *context* conditions as antecedents to attitude and perceived behavioral control in the context of explaining pro-environmental behavior (Ertz et al., 2017; Novoradovskaya et al., 2021). Therefore, we integrate these two variables in our analysis. The resulting model to describe TGRS usage is presented in Figure 18.

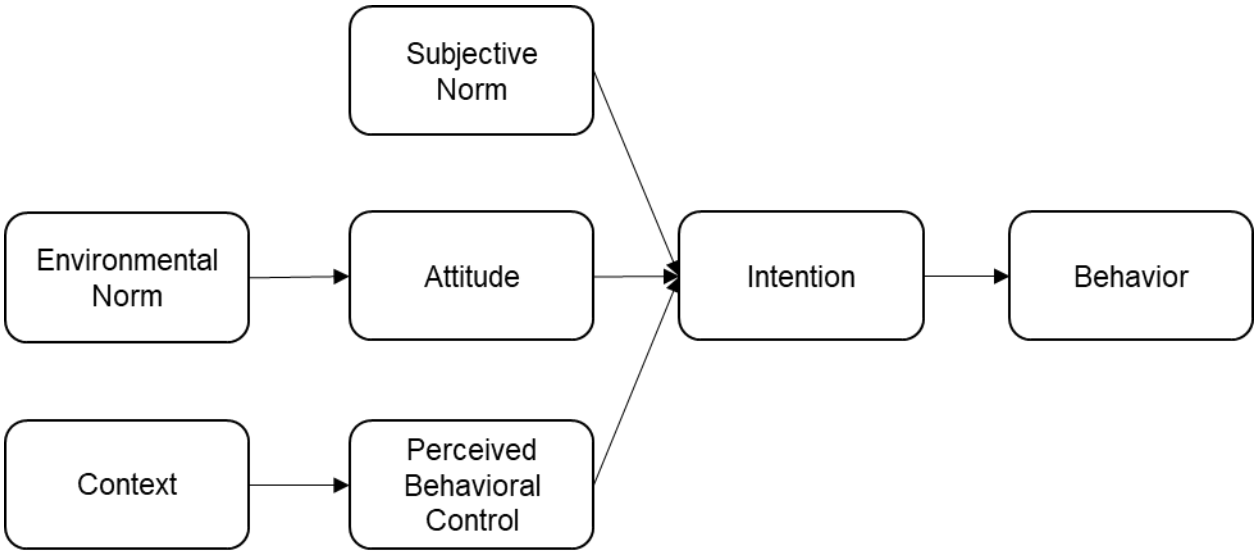


Figure 18: Adapted Theory of Planned Behavior

The variables in Figure 18 are valuable potential levers for initiating interventions that increase the usage (i.e., behavior) of TGRS. Intervention research on fostering pro-environmental behavior in general is rich (e.g., Schultz & Kaiser, 2012; Steg et al., 2014; van Valkengoed et al., 2022). In terms of TGRS interventions specifically, only two studies exist: Both Novoradovskaya et al. (2021) and Poortinga and Whitaker (2018) demonstrate the effectiveness of interventions such as providing informational material on the environmental impact of one-way plastics to customers or offering choice alternatives to plastic cups (e.g., free reusable cups). Given the availability of over 90 interventions for behavioral change (Novoradovskaya et al., 2021), the topic of TGRS still has many untapped possibilities for driving usage rates. However, evaluating such a large number of different intervention strategies is tedious, which is why different classification schemes for interventions have emerged (Messick & Brewer, 1983; Steg & Vlek, 2009; van Valkengoed et al., 2022). On a simple level, one well-established differentiation divides interventions between (1) informational strategies and (2) structural strategies (Messick & Brewer, 1983; Novoradovskaya et al., 2021; e.g., Steg & Vlek, 2009). Steg and Vlek (2009, p. 313) define informational strategies as "changing perceptions, motivations, knowledge, and norms, without actually changing the external context in which choices are made". Structural strategies are seen as "changing contextual factors such as the availability and the actual costs and benefits of behavioral alternatives" (Steg & Vlek, 2009, p. 313). To give an example based on the study of Novoradovskaya et al. (2021), showing informational videos on the harmful effects of one-way plastic would classify as an informational strategy, while providing a free reusable cup portrays a structural strategy.

Summarizing, first research looks into interventions for TGRS, but given the stagnation of usage rates, the perfect solution has yet to be founds. With the urgency of tackling climate change, the need for more innovative solutions to drive pro-environmental behavior becomes evident.

The Role of Digital Innovations for Pro-environmental Behavior

Given its tremendous innovative potential, digital innovation and associated research bring substantial opportunities for fostering sustainable development (Thomas et al., 2020). As a consequence, many studies assess the potential of digital innovation for sustainability and interventions targeted at sustainable behavior (e.g., Bähr & Fliaster, 2023; George et al., 2021; Joukhadar et al., 2023). Next to many studies on specific instances of digital innovation and the respective digital technologies used to drive pro-environmental behavior (e.g., M. Berger et al., 2022), there are also few approaches to systematizing effects on sustainable transformations. Seidel et al. (2013) establish two central affordance categories in the context of organizational sustainability transformations. "Organizational sensemaking", which describes the use of digital technologies to support the understanding of complex interrelationships in the context of sustainable development and "sustainable practicing" as the use of technology for the operational implementation of sustainable business processes. Midden et al. (2007) provide four different roles of digital technologies in its interaction with people concerning pro-environmental behavior: Digital technology as (1) an intermediary, (2) an amplifier, (3) a determinant, and (4), a promoter. Given the substantial indications in other contexts (e.g., M. Berger et al., 2022; Boncu et al., 2023; Zawieska et al., 2022), we are confident that the possibilities of digital innovation (and its incorporated digital technologies) for driving TGRS are manifold and worth being investigated. However, the context of TGRS specifically has not yet been in focus, hindering the exploitation of its value for sustainability. In the following, we attempt to bridge this gap. To structure the applications of digital innovations not only in terms of the TPB impact factors but also in terms of different types of interventions, we combine insights from the differentiations of Seidel et al. (2013) and Steg and Vlek (2009). As a result, we differentiate between *information-based applications* (building on informational strategies of Steg & Vlek, 2009 and organizational sensemaking of Seidel et al., 2013) and *process-based applications* (building on structural strategies of Steg & Vlek, 2009 and sustainable practicing of Seidel et al., 2013). Therein, information-based applications are centered on increasing information access to consumers while process-based applications make changes to all business processes involved in the ordering, use, and return processes.

4.2.2 Research Methodology

Pre-study

In order to test the relationships proposed in Figure 18 in the context of TGRS, we conducted an online survey-based pre-study with the tool Unipark. Given the regional peculiarities of TGRS regulations, the survey targeted German residents. After presenting general information on the survey and an explanation on the term TGRS, the participants were queried on their actual usage behavior and the respective impact factors. The constructs were quantified via previously validated 7-point Likert scales (Likert, 1932), basing the variables *behavior* on Fishbein and Ajzen (2011), *attitude*, *subjective norm*, *perceived behavioral control*, *context*, and *behavioral intentions* on Ertz et al. (2017) and Fishbein and Ajzen (2011), and finally, *environmental norm* on Steg et al. (2014). The full survey is presented in Appendix D.1.

To attract potential respondents to the survey, the questionnaire was promoted by providing the link to the survey via social media platforms such as Facebook. Additional respondents were recruited via the SurveySwap respondent exchange and university mailing lists. After completion of the field phase, a data review took place to weed out erroneous cases. The final sample for analysis consisted of n = 197 valid subjects. To ensure a high quality of the sample, 11 subjects were excluded due to incorrectly answering a control question. In order to check whether the individual statements allow the formation of a reliable overall indicators, a reliability analysis was conducted by determining Cronbach's alpha (Cronbach, 1951) and Pearson’s correlation (Pearson, 1896) for the underlying items of each construct. After removing one item from the construct *perceived behavioral control*, all Cronbach’s alpha and correlation values were >0.8, demonstrating a high reliability (Kuckartz, 2013). For the pre-study, four different linear regression models were calculated to perform the linear regression analysis (Figure 19). After testing and correcting for the requirements of linear regressions (i.e., interval scaling, existence of linear relationships, normal distribution of residuals, absence of autocorrelation, homoscedasticity, and the absence of multicollinearity; Fromm, 2012; Kuckartz, 2013), the models were estimated using the statistics software SPSS.

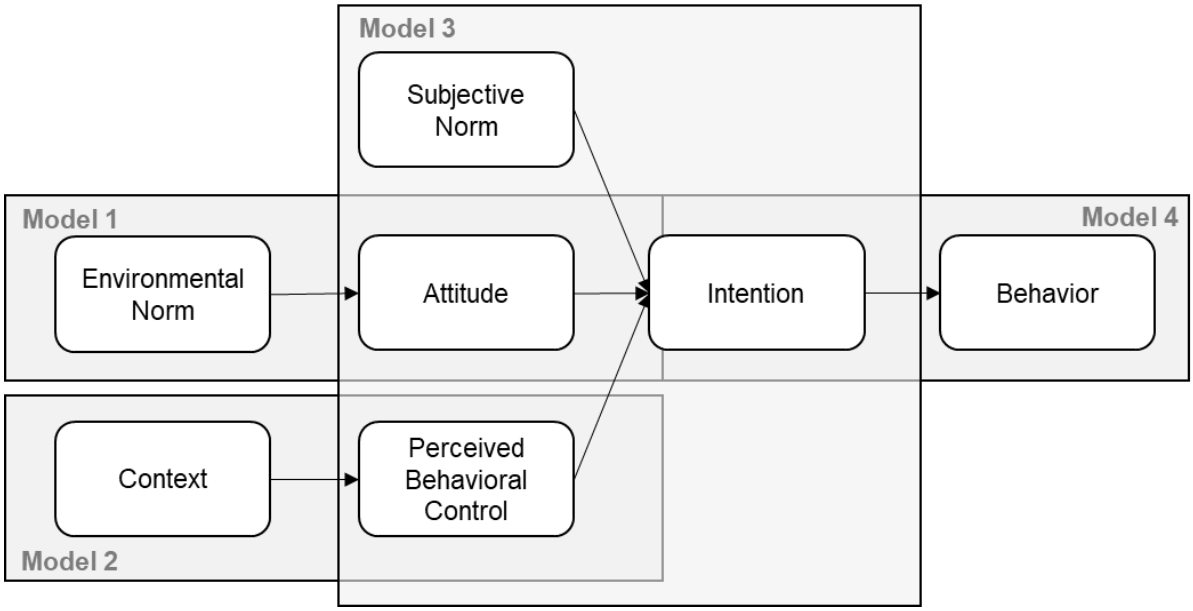


Figure 19: Regression Models

Market Analysis

After validating the relevant impact factors of sustainable behavior in the TGRS context from a customer perspective in the pre-study, the second part of this subchapter investigates how digital innovations are currently applied in real-world TGRS companies in order to improve the customer experience and thus usage rates. To get a realistic insight on how companies leverage digital innovations, we conducted a market analysis on 21 TGRS companies that operate in Germany, ranging from cup/ dish producers to the operators of multiway systems. Appendix D.2 presents an overview of the specific business focus of the firms selected. Building on Amalia et al. (2020), we conducted a two-phased web search to select the focal companies: 1) Company identification and 2) content analysis. For the company identification, the goal was to create a sample as comprehensive as possible in order to best analyze existing applications of digital technologies in TGRS firms. However, to date there is no comprehensive database on all existing TGRS firms in Germany. Therefore, the identification was conducted using multiple databases on existing TGRS companies in Germany (Blauer Engel; Deutsche Umwelthilfe; Löw et al., 2021). Of all the firms mentioned in the three databases, two criteria guided the selection: 1) firms operating in Germany and 2) firms that are involved in a pool TGRS system as described in Subchapter 4.2.1.

For the content analysis phase, multiple data sources were used for each of the firms in the sample: First, the homepage of the company was used as a starting point to better understand the product offering and digital services. Second, social media outlets such as YouTube

channels, or Facebook and Instagram accounts were analyzed. Third, if available, we tested the mobile applications of the respective TGRS firms to understand its functionality. Lastly, we screened for third-party reports to see if any other application of digital innovations was mentioned.

The resulting data sources were coded with reference to (Wolfswinkel et al., 2013) and thus a process of open coding, axial coding, and selective coding (Corbin & Strauss, 2008; Wolfswinkel et al., 2013). For open coding, given the explorative nature of the research question, we started off by simply highlighting relevant information on the application of digital innovations in TGRS. Afterwards, we applied axial coding to group, differentiate, and rename all the codes previously collected in order to create a set of codes detailing the application of digital innovation across TGRS companies (Corbin & Strauss, 2008). Lastly, selective coding was used to sort the codes into the impact factors identified in the pre-study, as well as the differentiation between information-based and process-based applications, resulting in a matrix of digital applications presented in Subchapter 4.2.3 below.

4.2.3 Results

Pre-Study

The survey conducted as part of the pre-study had a total of 197 participants. The consideration of various socio-demographic aspects enables a better understanding of the underlying sample. The sample is made up of 38.1 % (n = 75) male and 61.4 % (n = 121) female participants. One person (0.5 %) stated their gender as diverse. Accordingly, women are more frequently represented in the sample than men and diverse persons. Almost three quarters of the participants have a university degree (74.1 %; n = 146). Just over half of the respondents belong to the group of students (52.8%; n = 104). 41.6 % (n = 82) of the respondents stated that they were employed. This distribution is also reflected in the age structure. With 77.2 % (n = 152), the group of 21 to 29-year-olds is most represented. The second largest category is the 30 to 39-year-olds with 8.6 % (n = 17). Overall, the sample shows that there is no gender balance and that younger people are represented much more frequently than older people. In addition, the proportion of academics dominates compared to people with other educational qualifications. The impact of this difference between the German national demographics and the sample are discussed in Subchapter 4.2.4.

Table 13 shows the result of the linear regression analyses of the four models assessing impact factors of TGRS usage that were presented in Subchapter 4.2.2.

Predictor	***ß***	$ß_{standardized}$	***p***	R^2
Model 1 (Dependent variable: attitude)				
Environmental norm	0.504	0.429	< 0.001***	0.184
Model 2 (Dependent variable: perceived behavioral control)				
Context	0.603	0.636	< 0.001***	0.404
Model 3 (Dependent variable: behavioral intention)				
Attitude	0.440	0.339	< 0.001***	0.345
Subjective norm	0.405	0.276	< 0.001***	
Perceived behavioral control	0.162	0.164	0.008**	
Model 4 (Dependent variable: behavior)				
Behavioral Intention	0.270	0.375	< 0.001***	0.137

* p < 0.05; ** p < 0.01; *** p < 0.001

Table 13: Regression Results for Impact Factors of To-go Reusable System Adoption

The highly significant positive impacts of all predictor variables in each of the four models validate the relevance of the impact factors derived from literature. Therein, the pre-study demonstrates that higher TGRS usage rates can be achieved through the strengthening of environmental norms, the context, subjective norms, attitude, and perceived behavioral control. Building on the pre-study, the five identified impact factors for TGRS usage are selected as relevant intervention points targeting an increase in TGRS usage. In the following, we address how digital innovations are applied to leverage the positive influence of the five factors.

Market Analysis

The market analysis of TGRS companies yielded various different applications of digital innovations at the customer interface, which could drive TGRS usage rates. Table 14 presents the full list of applications detected, structured by the impact factors of TGRS usage and the differentiation between information-based and process-based applications. Given that environmental norm only impacts attitude and context only impacts perceived behavioral control, we merge the respective two variable pairs in Table 14 for clarity. Below each

application, the numbers written in cursive in brackets refer to exemplary TGRS companies (cf., number in Appendix D.2) leveraging this application.

Impact Factor	Information-based applications	Process-based applications
Environmental norm & Attitude	• Display of environmental benefits of TGRS (website, social media, mobile application) (e.g., 8, 13, 14) • Display of environmental destruction of one-way systems (website, social media, mobile application) (e.g., 1, 9, 10) • Display of new partners, product development, effects, company awards (newsletter, website) (e.g., 2, 11, 19)	• Provision of bonuses and vouchers within mobile application (e.g., 7, 8) • Integration of usage levels and award badges for mobile application usage (e.g., 8, 20)
Context & Perceived behavioral control	• Integration of interactive map with all participating partners (website, mobile application) (e.g., 18, 19, 20) • Integration of reminders on return deadlines in mobile application (e.g., 16, 19)	• Development of new sensor-based return vending machines (e.g., 3, 12) • Integration of returns in existing return vending machines (e.g., 6) • Automation of reordering processes based on data (e.g., 6) • Integration of QR/ EAN codes on cups and bowls (e.g., 1, 4, 14) • Billing of deposit within mobile application (e.g., 16, 18, 20) • Integration of partner recommendation tool (e.g., 8, 16,)
Subjective norm	• Presentation of existing partners and consumers (website, social media) (e.g., 5, 12) • Invitation of friends within the mobile application (e.g., 18, 20)	• No applications identified

Table 14: Applications of Digital Innovation in To-go Reusable System Firms

Environmental norm and attitude:

A number of digital innovations have been implemented in the company sample, which either target the environmental norm of customers or directly try to improve customers' attitude towards TGRS.

On the information side, a number of different digital channels can improve customers' access to information due to better accessibility and more diverse outlets than traditional, non-digital information sources (Gu et al., 2014). Leveraging this potential of digital innovation to improve the information flow, TGRS firms publish information on their social media (e.g., YouTube, Instagram, Facebook), on their corporate website, via newsletters, and (if available) in mobile applications. Bridging the on- and offline world, some of the inspected companies provide flyers at their partner stores, on which QR-codes lead to more information in the digital realm. Playing into the positive impact of environmental norms, companies make use of two strategies: (1) providing information on the negative, destructive impact of using one-way cups and dishes and (2) providing information of the potential benefits of using TGRS. Both strategies potentially increase customers' motivation to participate in TGRS, given the increased transparency on why reducing waste is important. Targeting customers' attitude directly, companies have also used these digital touchpoints to provide information on new product features, new partnerships, corporate awards, or general developments in the company on order to improve their image. Knowing how positively a company and their product (in this case TGRS) are developing can improve the attitude towards using such a product.

In terms of process-based applications, we observe two applications of digital innovation to improve the attitude towards TGRS. First, mobile applications can integrate vouchers or bonuses (e.g., discounts on drinks, etc.) that are easily accessible and usable in the respective TGRS partner store. Receiving vouchers can motivate customers to use TGRS more frequently due to a better attitude towards the company. Second, one firm integrated a level system within their mobile application, in which consumers can receive badges and awards for using the app frequently. Such elements are referred to as gamification, which describes "elements drawn from game designs to make tasks more engaging" (De Liu et al., 2017, p. 1011). Tasks, in our context, refers to the usage of TGRS. Gamification has already been proven as effective in contexts related to sustainable consumption (Koivisto & Hamari, 2014).

Context and perceived behavioral control:

The context describes the general conditions in which a TGRS is situated in, in particular in respect to the availability of TGRS itself. Perceived behavioral control then describes customers' perception of the context in terms of the ease of using TGRS. While we observed many process-based applications for both impact factors, we did not observe any information-based applications targeting the context, which is mainly due to the fact that information on the context does not change the objective context itself, rather it affects the perceived behavioral control in respect to the context.

On the information side, almost all of the companies within the sample have developed an interactive digital map which displays the participating partners in the TGRS system (e.g., bakeries, cafés, stores, etc.). Such as map increases transparency on where to buy and return cups (and the respective drinks) and increases the perceived availability of TGRS locations. While analogue maps could also highlight locations of partners statically, integrating the high speed of change and individual search functionality would not be feasible. Making use of customers' constant availability through mobile phones, few companies have also integrated automated reminders in their mobile application on when to return the cups and dishes to avoid financial penalties. This helps customers feel in control of the deposit process.

In respect to process-based applications targeting the context, companies have used digital innovations in several ways. Using QR and EAN codes on the cups and dishes, sensor-technology, cameras, and machine learning based image detection, a new type of return vending machines is currently implemented by few companies. Such machines can be placed in or outside stores for the return of reusable cups and dishes. Their benefit lies in reducing the dependency on store opening times and employee availability and can also bridge areas with no participating stores. Therein, they improve the overall availability of return options within the context. Similarly, existing return vending machines for bottles are also being expanded into accepting reusable cups, with the same positive effects. Lastly, companies have used QR and EAN codes on their cups and dishes to scan and document every ordering and return of cups. The resulting data can be used to analyze and predict the demand and flow of cups and dishes in order to optimize and automate the ordering processes for cups. As a result, there are less periods with no available cups, also improving the availability.

In terms of perceived behavioral control, the QR or EAN codes enable to track every movement and order/ return of the cup. This information can also be tracked by customers in order to

monitor, if there are any unreturned cups linked to oneself. The risk of losing oversight of open orders and deposits thus disappears. In addition, companies integrated the deposit process in the mobile app, to automate its calculation and billing. This increases the ease of use for customers because they do not need to carry cash or deposit tokens. Lastly, we observed a company offering a digital tool through which consumers can recommend a store, bakery, etc. as a potential new partner for the TGRS. The TGRS company then contacts the recommendation in order to broaden its partner network. This creates stronger involvement of customers and more perceived control on who is participating. Using a digital tool for recommendation reduces the times effort needed to provide a recommendation.

Subjective norm

Lastly, customers are heavily influenced by their perception of the favorability of TGRS to their peer group. Surprisingly, we found very little evidence of leveraging the impact of subjective norms when assessing the application of digital innovations. There are only two examples of an information-based application we could observe: (1) the integration of videos and posts of people and companies already using TGRS and reporting on their positive experience, which could increase customers' perception that using TGRS is desirable in society and (2) a mobile application that includes an online tool for inviting friends to use the app. For the second example, the firm pledges to donate money to a charity for every new customer. We did not find any indication of a process-based application for addressing subjective norms.

4.2.4 Discussion

To tackle the overconsumption of resources and excessive waste creation, new ways to reduce waste are important. Reusable cups and dishes for beverages and food in the "to-go" area are one possibility for this aim. However, with stagnating usage rates of TGRS, the question of how to proceed still remains. This subchapter targets this issue by first identifying the relevant impact factors for behavioral intentions and use behavior in respect to TGRS and second, assessing how practitioners currently leverage digital innovation in their quest for increasing usage rates. We present 15 applications of digital innovations in TGRS companies at the customer interface, structured along the impact factors of use behavior (environmental norm, attitude, context, perceived behavioral control, and subjective norms) and the differentiation between information-based and process-based applications.

The subchapter contributes to research and practice in three ways. First, we draw a clear picture of how industry currently leverages digital innovation at the customer interface in order to improve TGRS usage rates and the corresponding customer experience. Therein, we are the first to pinpoint how digital innovation is used as a lever for more sustainable consumption in this context. Research heavily discusses the diverse possibilities of digital innovation for sustainability behavior (e.g., Bähr & Fliaster, 2023; George et al., 2021; Joukhadar et al., 2023). This subchapter expands previous insights by assessing not only what could be done in theory, but what is really done in practice in the context of TGRS. Second, the pre-study offers a validated model of factors impacting peoples' usage behavior and intention in respect to TGRS. Such a contextualization (Hong et al., 2014) helps to better understand the context of TGRS which is crucial for driving its adoption. Lastly, the matrix in which we structure the applications of digital innovation in a TGRS context offers a potential framework also for assessing the role of digital innovation in driving pro-environmental behavior in other domains. The framework helps to better understand the different possibilities of digital innovation and eases the spotting of gaps in terms of application possibilities.

Theoretical Implications

On a theoretical plane, this subchapter builds on and extends previous insights in the realm of pro-environmental behavior and TGRS. In respect to the TPB, we validate and contextualize the model proposed by Ertz et al. (2017) in the specific context of TGRS. While offering support for the central role of the context, we expand Ertz et al.'s (2017) take on the impact of motivation on attitude investigated in their study. Agreeing that the overall motivation regarding a certain behavior has a positive impact on the attitude, we argue for an additional integration of environmental norms in the context of TGRS, given the strong focus on sustainability and positive environmental benefits associated with usage. Relating back from our specific model to the general TPB model (Hong et al., 2014), our results thus hint at the importance of including context-specific norms (e.g., social sustainability norms, environmental norms, social norms) when contextualizing TPB models. Looking at applications of digital innovation to improve TGRS usage rates, we complement the findings of Novoradovskaya et al. (2021) and Poortinga and Whitaker (2018). Both studies show the effectiveness of individual strategies (i.e., informational videos, informational posters, provision of free reusable cups, vouchers and discounts) for increasing TGRS usage. We demonstrate the transferability of some of those strategies (e.g., informational posters, vouchers) to the digital realm and provide a structured

overview of additional applications. This provides the baseline for a comprehensive testing of the effectiveness of individual and sets of applications of digital innovation.

In addition, our work also pinpoints gaps between research and practice, which are important to close in order to drive pro-environmental behavior more thoroughly. The different impact factors of TGRS usage are addressed by companies in varying intensity. While applications of digital innovation to increase information access regarding TGRS and to improve access to lending and return stations are already widespread, one factor is largely dismissed so far: subjective norms. Research on the role of subjective norms and the role of digital innovation for leveraging social norms through nudges is widespread in many contexts, such as fake news detection or pro-environmental behavior (M. Berger et al., 2022; Gimpel, Heger, et al., 2021; Keller et al., 2021; Liu et al., 2017; Ruokamo et al., 2022). However, looking at only two applications of digital innovation in practice, TGRS firms have not yet implemented the results achieved in research. For research, this indicates a strong need to analyze, which insights and artefacts could better support practice in transferring the knowledge on subjective norms to TGRS practice.

Practical Implications

This subchapter provides practitioners with a benchmarking list of digital opportunities in the TGRS context. When TGRS firms aim to improve usage rates, they can take the 15 applications of digital innovation and analyze, which of them are not yet implemented. Besides this main practical contribution, our analysis yielded two central implications for practice.

First, during our analysis, we observed a significant disbalance between ownership of customer touchpoints and interest in driving TGRS adoption. TGRS firms who have an inert motivation (both economically and environmentally) to drive TGRS usage rates do not usually have any customer touchpoints at the point of sale (i.e., the purchase of beverages and food). Their customers are not the consumers of beverages and food, but the partners (cafés, bakeries, restaurants, stores) handing out their reusable cups and dishes. As a result, their communication is often B2B-centered with a main priority on generating new partners for their company. Those partners, in turn, own the customer touchpoints at the point of sale and could therefore significantly drive usage rates of TGRS, for example by taking reusable cups as a default or always suggesting the sustainable alternative. Those partners, however, often offer TGRS because it is a legal requirement and do not necessarily have an incentive for motivating customers to opt for the sustainable alternative. Both policy makers and TGRS firms thus

urgently need to consider how to better involve and incentivize retailers for advertising TGRS instead of one-way systems.

Second, many of the applications of digital innovation we spotted were focusing on an improvement of the return process, as the thought of having to carry around used cups is still a significant barrier to many customers. During the analysis, it became quite clear that much of the discomfort stems from the scattered TGRS market with many different firms operating their own isolated TGRS, naturally reducing the number of partners (and thus return options) within each system. For practitioners, considerations on better bundling or making different providers compatible in the return system would be a step towards driving usage behavior, even though it comes with economic downsides.

Limitations and Future Research

As with any other research, this subchapter is subject to limitations. The market analysis is based only on information available to the public for example on websites or social media. While we chose this approach to cover a broad range of firms, it excludes more detailed assessments of individual companies, for example through employee interviews or workshops. As a consequence, future research could expand our findings by conducting single or multiple case studies. In addition, given the strong impact of local regulations and the peculiarities of a country's attitude towards multiway systems this subchapter focuses only on one country – in this case Germany. An extension to other countries could yield both similarities but also differences in technology usage not yet included in the results. To give practitioners precise recommendations on which applications to implement in which order, a relevant next step is to empirically test the effectiveness of different digital applications, for example through A/B testing.

A further limitation of the study results from the underlying sample in the pre-study phase. From a gender-specific perspective, women (n = 121) are more frequently represented than men (n = 75) and diverse persons (n = 1). In addition, the age group of 21-29-year-olds makes up the majority of the sample at 77.2% (n = 152). The results therefore only represent the entire German population to a limited extent. The impact factors identified in the pre-study mainly relate to the younger generations. Future research could analyze any potential differences in TGRS acceptance between age groups, for example caused by different levels of affinity for digital technologies.

Lastly, the focus of this study is on individuals and their choice to use or reject sustainable packaging alternatives. Future research could expand on the finding with a societal and policy-centered perspective that analyzes which regulations or societal dynamics can improve pro-environmental behaviour.

In summary, this subchapter explores the role of digital innovation for driving customer adoption of sustainable alternatives in the external innovation environment. For innovators aiming to launch sustainable products, acknowledging and actively shaping the external environment is critical for economic, social, and environmental success.

5 Outcomes of Digital Innovation for Sustainability

Organizations conduct digital innovation actions within the internal and external innovation environment. These actions then lead to sustainable digital innovation outcomes (Kohli & Melville, 2019). In digital innovation for sustainability, outcomes comprise products, services, processes, and business models (Ciriello et al., 2018; Kohli & Melville, 2019; Nambisan, 2013). However, identifying the potential spectrum of specific innovation outcomes is not trivial. Therefore, a thorough assessment of different contexts and their potential digital innovation for sustainability outcomes is important to maximize the value for sustainable development. In the following, one prominent context for outcomes of digital innovation for sustainability is highlighted, building on Christmann et al. (2022) and Christmann et al. (2024) for most parts.

One central context for sustainable development is sustainability in cities. Cities are the main contributor to global energy demand and carbon emissions (World Economic Forum, 2020), making them a key lever for addressing the climate crisis (Corbett & Mellouli, 2017; Gimpel, Graf, & Graf-Drasch, 2020). The rising concentration of people in cities brings up the question of how these populations can best be provided with food – especially in times of uncertain global events such as pandemics or wars. Although worrisome, these challenges constitute a "window of opportunity" for innovative organizations. Researchers and practitioners are increasingly pointing to "urban agriculture" – a promising complement to traditional rural agriculture that involves growing crops and raising livestock in cities (M. Carolan, 2020; Langemeyer et al., 2021). However, significant hindrances exacerbate realizing the potential benefits of urban agriculture: First, urban spaces – characterized by sealed surfaces and heat stress – are a hostile habitat for many species, creating challenging environmental conditions leading to a high energy and material usage (Gimpel, Graf-Drasch, et al., 2021; Lüttge & Buckeridge, 2020). Second, urban agriculture often fails to compete economically due to high investment costs in prime city land and required workforce (Azunre et al., 2019; M. Chang & Morel, 2018) or governments restricting land use to very particular areas (Diehl et al., 2020). When turning toward traditional rural agriculture, digital innovation has proven to be a significant value lever for driving economic and resource efficiency (Steininger et al., 2022). In urban agriculture, however, how to leverage the potential of digital innovation for sustainability (i.e., smart urban agriculture) is less clear (O'Sullivan et al., 2019).

So far, researchers have primarily focused on understanding individual business use-cases of SUA. Thereby, they specifically examined SUA's digital infrastructure and its economic and

environmental impact (O'Sullivan et al., 2019; Weidner et al., 2022), as well as the social acceptance of the digital technologies used (Broad et al., 2021; Specht et al., 2016). However, many emerging SUA endeavors fail economically because of high investment costs, lacking skills, a wrong selection of technologies during implementation, or the inability to materialize the expected financial, environmental, and social benefits in the long run (Langendahl, 2021). What organizations urgently need to master the challenges of digital innovation development and deployment in SUA and better prepare themselves for launching an endeavor in this field, is a clear understanding of the concept of smart urban agriculture and the associated digital innovation outcomes. Hence our research question reads:

What is smart urban agriculture and how can its value be leveraged?

To capture the essence of SUA across development, we take two different perspectives. First, there is no shared understanding of which digital technologies, data, and functionalities SUA constitutes. In perspective 1, we thus conceptualize the phenomenon of SUA as a taxonomy by analyzing the relevant dimensions and characteristics of SUA outcomes. Second, to leverage the value of SUA, a sound understanding of the organizational requirements and prerequisites for leveraging SUA – a concept called organizational readiness – is critical (Lokuge et al., 2019). In perspective 2, we thus develop 20 organizational readiness factors for SUA by conducting semi-structured interviews with 9 research scholars and 16 smart urban farmers. Inspired by research combining different methods in one work (Venkatesh, Brown, & Sullivan, 2016), we combine perspective 1 and 2 to gain completeness: Both perspectives aim to deliver a more complete picture than one isolated approach by complementing the insights of each other. This yields so-called “meta-inferences” – a key result of this research. Meta-inferences depict interpretations of our findings in an integrative view. They provide the opportunity to look beyond the limitations of a single perspective and take a stance in conceptualizing SUA holistically.

5.1 Theoretical Background

Smart Urban Agriculture

SUA has links to two research streams: urban agriculture and smart farming. First, urban agriculture refers to the food production, processing, and marketing in urban ecosystems (De Bon et al., 2010; Smit et al., 2001). It can range from private gardens for self-consumption to sophisticated concepts such as commercially oriented, high-tech indoor farms, mostly

producing vegetables, fish, and meat (Wood et al., 2020). As free space for traditional ground-based agricultural practices is scarce in most cities, some of these systems are aligned with growing food on housing facades, rooftops, or indoor greenhouses (Dorr et al., 2021; Specht et al., 2016). Second, smart farming refers to using digital technologies to optimize agricultural production in terms of efficiency, quality, and sustainability (Balafoutis et al., 2017; Köksal & Tekinerdogan, 2019). Key technologies implemented include cloud computing, the Internet of Things, or robotics (El Bilali & Allahyari, 2018). Robotics, for example, can control tractors, perform planting and mechanical weeding, sort and harvest fruits, or feed animals automatically (Nair et al., 2021).

In synthesizing the understanding of urban agriculture and the description of smart farming, we define SUA as the use of modern digital technologies to optimize food production in urban ecosystems in terms of efficiency, quality, and sustainability. SUA is promising for tackling the challenges of urban agriculture, by, for example, providing tools to automatically control environmental parameters (e.g., temperature, humidity) of cities (Goldstein et al., 2016; O'Sullivan et al., 2019). In addition, SUA enables the creation of entirely new concepts, such as closed-fielded vertical farming (Maye, 2019).

A Taxonomy for Smart Urban Agriculture

When developing digital innovations for SUA, high levels of knowledge regarding the specific contexts' possibilities for applying digital technologies are required (Kohli & Melville, 2019). As application knowledge is highly context-specific, a closer analysis of SUA outcomes is essential to drive SUA innovation. Understanding the different dimensions on which SUA can differ is needed to master opportunity detection and development. To address this need, developing a taxonomy pinpointing dimensions of SUA deems a promising approach (Nickerson et al., 2013).

Building Block	Description	Source
Digital technology	All soft- and hardware of the solution and its combination of information, computing, communication, and connectivity technologies	(Bharadwaj et al., 2013)
Data	Types, handling, and interaction of and with data	(Püschel et al., 2022)
Approach	The type of urban agriculture applied both with respect to end products and growing and harvesting methods	(Lanyu Li et al., 2020)

Table 15: Building Blocks of Smart Urban Agriculture

In SUA, digital technologies, referring to the combination of information, computing, communication, and connectivity technologies, including the related hard- and software, are at the core (Bharadwaj et al., 2013). Understanding SUA applications thus requires three components: the digital technology (hard- and software) itself (Bharadwaj et al., 2013), the data these technologies work with to generate meaningful insights (R. Zhang et al., 2019), and lastly the specification of the context, namely the selected SUA approach in which the digital solution is applied (Hong et al., 2014). In line with our understanding of IS research covering the interaction between information technology, information, and people, the three presented components are suitable building blocks in the taxonomy and serve as a structuring tool for the different dimensions (A. S. Lee, 2010). Table 15 summarizes the building blocks.

Organizational Readiness for SUA

Many digital innovation endeavors fail during the implementation and exploitation phases, for reasons such as financial challenges or difficulties with scaling (Battistella et al., 2021; Deserti & Rizzo, 2020; Roundy, 2017). Addressing this challenge, the concept of organizational readiness factors as necessary prerequisites to successfully implement and exploit the potential of an opportunity is emerging (Lokuge et al., 2019; Molla & Licker, 2005). In the context of SUA, the underlying "organization" can range from large-scale professional firms, community-based public endeavors up until private household projects (Wood et al., 2020). As the readiness to innovate with digital technologies is associated with seizing business opportunities (Walczuch et al., 2007), Lokuge et al. (2019) propose an organizational readiness model for digital innovation in general. The model identified seven possible areas of organizational readiness for digital innovation (namely resource readiness, IT readiness, cognitive readiness, partnership readiness, innovation valance, cultural readiness, and strategic readiness). However, as readiness often includes psychological and structural factors, such as the commitment and capability to change, readiness models must be tailored to account for the attributes of the specific technology or context (Molla & Licker, 2005).

5.2 Research Methodology

In analyzing the contextual implications of SUA outcomes, we apply taxonomy research (perspective 1) and the development of organizational readiness (perspective 2). Inspired by meta-inferences in mixed-methods research (Venkatesh, Brown, & Sullivan, 2016), we derived an integrative view of both perspectives, which provides a fuller picture of the phenomenon

under investigation and links both perspectives. The meta-inferences were developed in an inductive process of combining insights from all combinations of SUA's taxonomy dimensions and SUA's readiness categories to form broader generalizations. Thereby, we aimed at identifying causal mechanisms between both perspectives (Venkatesh, Brown, & Sullivan, 2016). Starting with perspective 1, we built the taxonomy following Kundisch et al. (2022) who align with but extend Nickerson et al. (2013) (see Appendix E.1 for an overview of the taxonomy design's phases). After specifying the taxonomy's purpose (*Phase 1: Identify the problem and motivate*), we proceeded to define the taxonomy's meta-characteristics, ending conditions, and evaluation goal (*Phase 2: Define objectives of a solution)*.

Meta-characteristic and ending conditions: Following Nickerson et al.'s (2013) advice, we defined the meta-characteristic of our taxonomy as *Characteristics of digital technologies in urban agriculture*. To iteratively evaluate whether our taxonomy had reached quality saturation, we chose a set of objective 'ending conditions' (Nickerson et al., 2013): (1) no new dimensions or characteristics were added in the last iteration, (2) no dimensions or characteristics were merged or split in the last iteration, and (3) every dimension is unique and not repeated, (4) at least one object is classified under every characteristic of every dimension. In addition, we applied the subjective ending conditions proposed by Nickerson et al. (2013), which require a taxonomy to be *concise*, *robust*, *comprehensive*, *extendible*, and *explanatory*.

#	Approach*	Basis	# of Changes in Last Iteration	Taxonomy
1	c-e	"Web of Science" literature	8 dimensions, 27 characteristics	8 dimensions, 27 characteristics
2	c-e	AIS eLibrary literature	4 dimensions, 15 characteristics	11 dimensions, 36 characteristics
3	c-e	Interviews with 9 researchers	2 dimensions, 4 characteristics	10 dimensions, 33 characteristics
4	e-c	10 real-life examples	1 dimension, 9 characteristics	9 dimensions, 25 characteristics
5	e-c	32 real-life examples	No changes	9 dimensions, 25 characteristics
6	e-c	Interviews with 16 practitioners	Renaming of 1 dimension	9 dimensions, 25 characteristics

*c-e: conceptual-to-empirical; e-c: empirical-to-conceptual

Table 16: Iterations of Smart Urban Agriculture Taxonomy Development and Evaluation

Overall, we conducted six iterations (*Phase 3: Design and Development)*. Iterations 1, 2, and 3 followed a conceptual-to-empirical approach (deductive reasoning), and iterations 4, 5, and 6 took an empirical-to-conceptual approach (inductive reasoning) (Kundisch et al., 2022). Table 16 details the six iterations.

Iterations 1, 2, and 3 (conceptual-to-empirical): During iteration 1, we conducted a systematic literature review (Boell & Cecez-Kecmanovic, 2015) of English-language research studies with the database Web of Science covering broad terminology in the SUA realm. Appendix E.2 summarizes the search protocol. For title, abstract, and full-text screening, we specified the following inclusion criteria: Studies addressing (1) urban contexts, (2) digital technologies, and (3) the production phase of agriculture. Two authors screened each of the resulting studies and extensively discussed their inclusion. After both screening iterations, 53 were considered. Additional studies were identified in the second iteration via a search of the AIS eLibrary, yielding eight more studies. The full list of 61 studies can be found in Appendix E.3. We drew on Wolfswinkel et al.'s (2013) approach to qualitative data analysis and coded all studies (see exemplary coding scheme in Appendix E.4). Specifically, during open coding, we first highlighted information on SUA technologies' characteristics. For axial coding, we then grouped the characteristics into dimensions. Afterward, we assigned the dimensions to the three building blocks *digital technology*, *data*, and *urban agriculture approach*. For selective coding, we reduced and refined the characteristics in each dimension. Iteration 3 was based on interviews with nine scholars (see Appendix E.5), whose feedback we used to refine the dimensions and characteristics. More information on the expert interviews, sampling strategies, and coding procedure is presented at the end of this subchapter. To assess the real-life fit of the taxonomy, we created a set of ten SUA technologies (Appendix E.6). Five of these digital technologies were identified from the literature, and the other five from real-life industry products. We built the sample based on three criteria: (1) technical aspects of digital technology described in detail, (2) advanced stage of development, (3) diverse types of urban agriculture (e.g., aquaponics, greenhouses). In each of the iterations, we classified the ten technologies using our taxonomy (Nickerson et al., 2013; Oberländer et al., 2019).

Iterations 4, 5, and 6 (empirical-to-conceptual): We compared real-life examples of SUA and identified similarities and differences (Nickerson et al., 2013). Iteration 4 leveraged the set of ten technologies which we extensively discussed and compared in light of our taxonomy. For iteration 5, we composed a more detailed list of 32 SUA technologies as an information source through a structured web search and classified these technologies using the taxonomy

(Appendix E.6 and E.7). Following Amalia et al. (2020), we conducted our web search as a two-phased approach: (1) Website identification and (2) content analysis. For website identification, we searched the internet with keywords related to "smart urban agriculture," "smart urban farming," and the individual SUA approaches (e.g., "vertical farming" or "hydroponics"). For the content analysis, we analyzed respective websites concerning the taxonomy's dimensions and characteristics by screening for any information indicating an assignment to the characteristics of the taxonomy. This final classification also served as a tool to objective ending conditions (3) and (4) (*Phase 4: Demonstration)*. In iteration 6, we evaluated the taxonomy (*Phase 5: Evaluation)* with 16 semi-structured interviews with practitioners to assess the attainment of the subjective ending conditions (see Appendix E.8 for the interview guideline protocol). We ensured the highest ethical standards by having our research approved by the University of Hohenheim Ethics Committee. We recruited our initial participants via personal networks and continued via snowball sampling. We stopped data collection after a total of 25 interviews as no significant new topics were brought up. Individual interviews lasted between 11 and 57 minutes (12.6 hours in aggregate). The interviewees resided in several countries, including Austria, Germany, Israel, and the Netherlands. We recorded and transcribed each interview.

We coded the interview data with reference to Wolfswinkel et al. (2013), applying a pattern-inducing technique by gathering qualitative data and clustering text segments into concepts. We compared new categories as they emerged and discussed their connection. While going back and forth between data and descriptive codes, we systematically distilled readiness factors of SUA. The coding process was divided into three stages: open coding, axial coding, and selective coding (Corbin & Strauss, 1990; Wolfswinkel et al., 2013). An exemplary coding scheme outlining the coding process is part of Appendix E.4. Due to the explorative nature of our research, one author started by thoroughly reading the interview transcripts and highlighting important text passages. This way, text passages on factors that could contribute to or prevent SUA organizations from using digital technologies were highlighted. During this *open coding*, we relied on informant terms close to the original interview data. For *axial coding*, we used a workshop to paraphrase and group the identified text passages, searching for similarities and differences among the codes (Corbin & Strauss, 1990). If agreements about certain codes were low, we revisited the transcripts, engaged in discussions, and developed mutual understanding and consensual decision rules. For *selective coding* the grouping was redefined, and categories of SUA readiness were built. By integrating existing literature (e.g., Lokuge et al.'s (2019)

digital readiness categories of *Resource Readiness, Cultural Readiness, Strategic Readiness, Innovation Valence, Cognitive Readiness,* and *Partnership Readiness)*, we evaluated our data asking whether the emerging categories help us to describe and explain the phenomena we were observing. Although presented linearly above, our analysis was dynamic and iterative. We continued coding new data and refining our findings until we reached theoretical saturation, where additional interviews did not yield any change in the readiness factors.

5.3 Results

Taxonomy Development and Evaluation

We build on literature, real-life examples, and interviews throughout the six iterations to derive our taxonomy (Figure 20). As outlined in subchapter 5.1, we use the tailored building blocks of *Digital technology*, *Data*, and *Approach* to structure SUA and cluster dimensions and characteristics in the three blocks (Bharadwaj et al., 2013; Püschel et al., 2022).

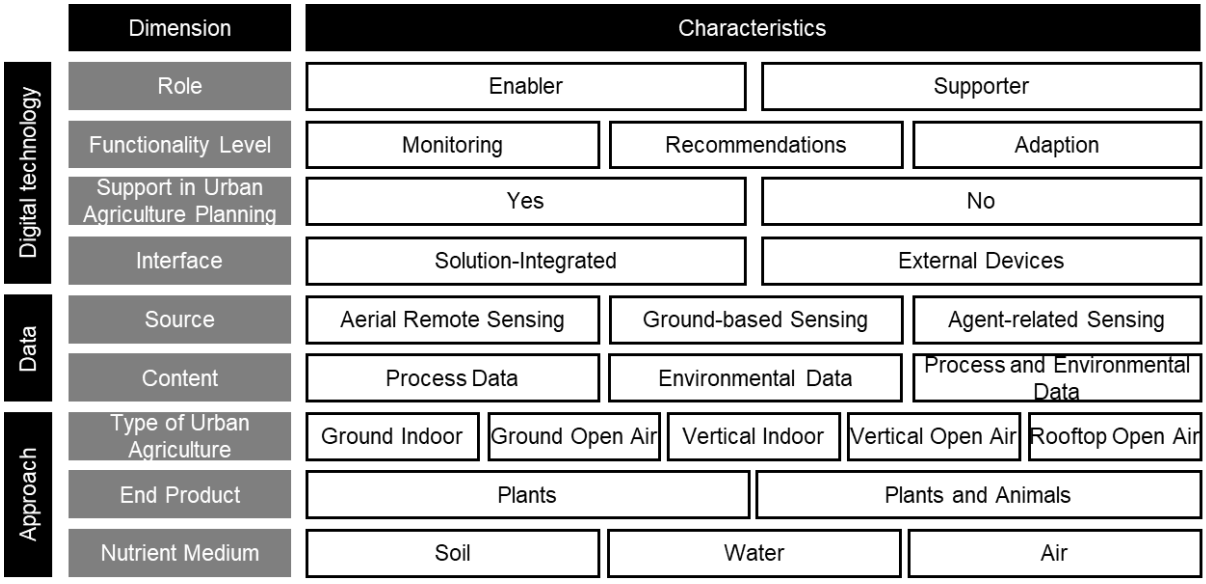


Figure 20: Taxonomy of Smart Urban Agriculture Technologies

Digital Technology: The first four dimensions relate to aspects of digital technology applied in the context of urban agriculture. Firstly, the *Role of Technology* indicates whether digital technology is a *Supporter* or an *Enabler* of the urban agriculture solution (Benbasat & Zmud, 2003; Hanelt et al., 2017). Supporters are digital technologies that improve existing solutions, for example, by reducing water resources required in a rooftop garden (Harada et al., 2018). By contrast, enablers are central components of urban agriculture solutions and are required for the solution to work at all. Examples include all types of highly automized robotic vertical farms,

where operations would completely still stand if the underlying digital technologies (such as robotics algorithms) stopped working.

Secondly, the dimension *Functionality Level* indicates the highest functionality level sorted from least to most advanced functionality. Therein, the higher functionality levels such as adaptation also include the lower levels such as monitoring. The characteristic *Monitoring* describes all activities (such as data collection and analyses) related to measuring and tracking parameters during operation without actively changing them (e.g., nutrient levels, sunlight) (Félix et al., 2018). The characteristic *Recommendations* goes one step further and involve actively recommending specific alternatives (e.g., adding more water) (Galdon et al., 2021). *Adaptation* either refers to a) environmental adaptation by actively controlling and changing environmental parameters such as light, irrigation, and nutrients (e.g., by modifying the light intensity) (Gravalos et al., 2019), or b) production adaption by performing actions directly on the product, such as smart harvesting or weed management (Ampatzidis et al., 2017; Farhangi et al., 2020; Ofori & El-Gayar, 2021). Those characteristics give insights into the smartness of SUA technologies. According to Alter (2020), the smartness of SUA technology depends on the technology's ability to use automated capabilities and physical, informational, technical, and intellectual resources to process, interpret and/or learn from information. Thus, the smartness of technologies classified in *Monitoring* is comparably lower than those in *Recommendations* which, in turn, has a lower level of smartness than *Adaption.*

Thirdly, *Support in Urban Agriculture Planning* involves using digital technology to find suitable spaces for urban agriculture or simulate different urban agriculture set-ups (Ghandar et al., 2021; Khan & Ahmed, 2017). SUA technologies either support this planning process (i.e., *Yes* characteristic) or do not (i.e., *No* characteristic). Lastly, the dimension *Interface* describes where humans and machines interact. An interface can be either directly integrated with the digital technology itself (S*olution-integrated),* through, for example, displays on the technology, or through *External Devices* such as wearables (Niemöller et al., 2019).

Data: The next two dimensions refer to the data collected, analyzed, and acted upon. This building block includes data collected directly by the operator or externals (e.g., weather data). Firstly, the *Source* refers to the location of data collection (Püschel et al., 2022). *Aerial Remote Sensing* describes data collected from drones and satellites in the air, for example, aerial images (Egerer et al., 2020). *Ground-based Sensing* refers to all ground-based data sources collecting and acting upon information such as temperature, humidity, or nutrient levels (Surantha &

Surantha, 2020). Lastly, *Agent-related Sensing* refers to data collected directly at and by human agents (e.g., farmers, technicians) within the SUA solution, such as activities and movements tracked by smart watches, mobile phones, or smart glasses (Niemöller et al., 2019).

Secondly, *Content* specifies what data are collected and used by the digital technology and differentiates between *Process Data*, *Environmental Data*, and their combination (*Process and Environmental Data*). Process data includes data on a machine's operations (e.g., irrigation performed, robotic movements), refers to data on the actual product (e.g., growth level or health status information; Ofori & El-Gayar, 2021), or includes interactional data that involves communication between humans and machines, such as human-generated input to the system (Nadal et al., 2017). Conversely, *Environmental Data* comprises information on the surrounding environment (e.g., CO_2 levels, topography) (Nadal et al., 2017). SUA endeavors operating on comprehensive data types include *Process and Environmental Data*.

Approach: The third set of dimensions relates to the underlying urban agriculture approach. Each urban agriculture solution can be classified according to its basic *Type*. Urban agriculture solutions are either classified as *Ground Indoor* (e.g., greenhouses, hydroponic systems), *Ground Open Air* (e.g., community gardens), *Vertical Indoor* (e.g., indoor vertical farms), *Vertical Open Air* (e.g., productive façades), or *Rooftop Open Air* (e.g., rooftop gardens) (Dorr et al., 2021). *End Product* comprises the agricultural products produced in the urban agriculture solution. Urban agriculture solutions can contribute to food security by producing *Plants* (e.g., vegetables) or *Animal and Plant* products (e.g., aquaponics combining plant cultivation in a hydroponic system and fish farming in an aquaculture system) (Padilla et al., 2018; Wood et al., 2020). The dimension *Nutrient Medium* indicates the nutrient medium used to produce the end product (Padilla et al., 2018). Growth environments include *Soil*, as in traditional agriculture or greenhouses, and *Water* or *Air*, as in hydroponic or aeroponic systems (Padilla et al., 2018).

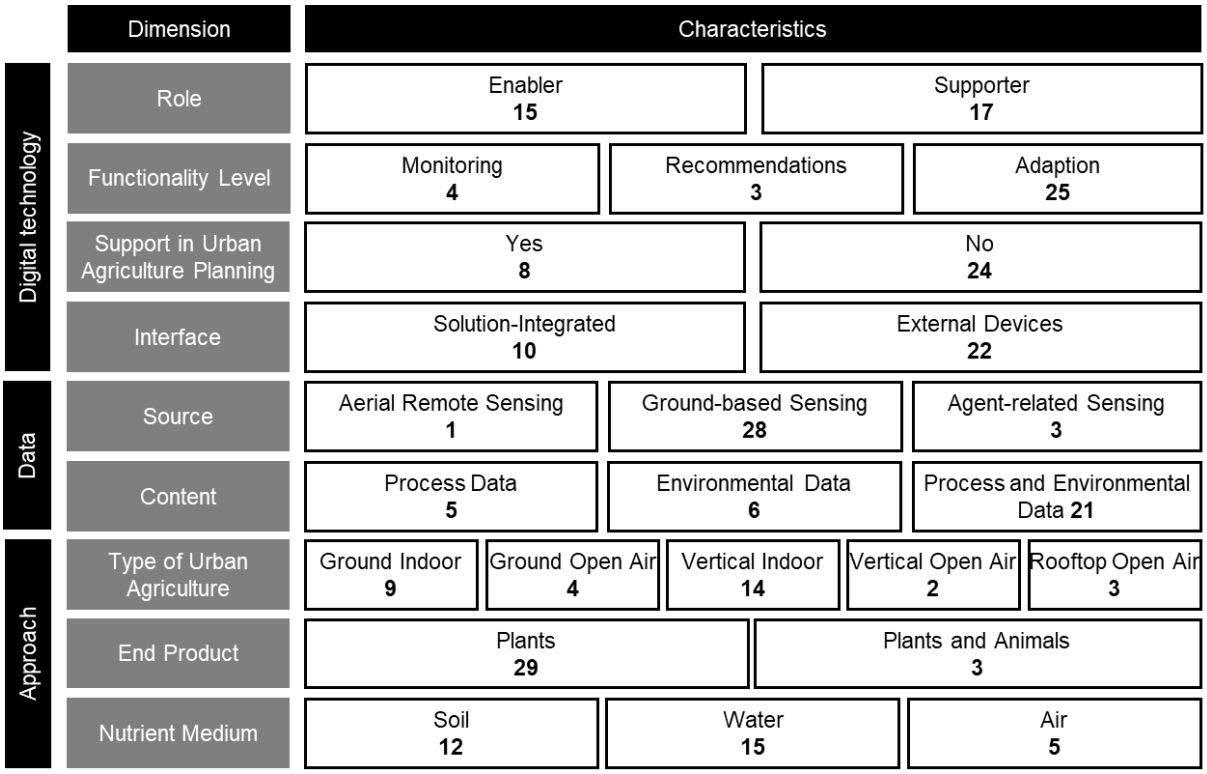


Figure 21: Technology Classification Using the Taxonomy of Smart Urban Agriculture

As detailed before, we classified 32 SUA technologies using the final taxonomy to first evaluate if all real-life examples are classifiable through our taxonomy, and second to test if every characteristic is addressable through at least one real-life example (objective ending conditions). Appendix E.7 lists the 32 technologies selected and their assignment to the different characteristics. Figure 21 shows the classification of these 32 technologies within the taxonomy. The number below the characteristics indicates how many SUA technologies were assigned to the characteristics. The classification proves that (1) all objects could be classified within the dimensions and characteristics, and (2) all characteristics were relevant to at least one SUA technology.

Readiness Factors in Smart Urban Agriculture

After conceptualizing the phenomenon of SUA as a taxonomy, interviews with 16 SUA practitioners on requirements and prerequisites needed for leveraging SUA laid the ground for the derivation of 5 SUA readiness categories that gather 20 SUA readiness factors. As stated in subchapter 5.2, we referred to Lokuge et al.'s (2019) proposed categories of digital readiness to gather emerging SUA readiness into categories. Table 17 presents our main findings: As shown in column one, most of Lokuge et al.'s (2019) readiness categories, namely, *resource readiness, cultural readiness, strategic readiness,* and *partnership readiness* were also relevant for SUA

readiness. Further, our data revealed a new readiness category, namely *regulatory readiness*. Column three represents detailed descriptions of each of the 20 readiness factors named in column two. For *resource readiness,* the readiness factors *IT infrastructure, IT expertise,* and *finances* are in line with (Lokuge et al., 2019), whereas *integration,* and *sustainability* turned out to be specifically relevant for SUA readiness. With *cultural readiness*, the existing factors *knowledge sharing, trial-and-error mentality, appreciation,* and *fun factor* are complemented by *culture of change* and *transdisciplinary mindset*. Moving on to *strategic readiness,* only *stakeholder awareness* is found to be relevant for SUA readiness, expanded by *scale* and *scale-up pace*. *Partnership readiness* complements the existing factor *personal network* with *high-tech supply availability, ecosystem integration,* and *training opportunities*. *Regulatory readiness* categories the newly found SUA readiness factors of *adherence* and *laws.* Finally, column four provides an exemplary quote from the interviews for transparency.

Readiness Category	**SUA Readiness Factor**	**Description**	**Exemplary Quote from Interviews** (ID of Practitioner)
Resource readiness	IT infrastructure	The organization must provide IT infrastructure (hardware, software, connectivity) to quickly leverage new technological opportunities the market provides (e.g., robotics, AI) as a response to evolving automation requirements in urban agriculture.	*I recently talked to our software manager about how far along we are with implementing adaptive AI systems. He just laughed at me and said we first have to build an AI system to then complement it with an adaptive system later. We are really at the beginning of this technology.* (ID16)
	IT expertise	The workforce must bring along a set of IT skills, such as machine learning and other data-science skills, to meet the requirements of high-tech SUA.	*[We are talking about] a new type of farmer with a high affinity for IT. That point is very important for future planning to make sure that farmers of the future bring skills and that type of knowledge with them.* (ID10)
	Integration	The market is required to offer standardized interfaces for high levels of integration but should also offer options for individualization and tailoring to meet the needs of urban agriculture organizations.	*The plan is to fully automate the regulations. That can only be realized effectively in close collaboration with our partners because they do not just sell a "product x," but a highly individualized one.* (ID12)

Readiness Category	**SUA Readiness Factor**	**Description**	**Exemplary Quote from Interviews** (ID of Practitioner)
	Finances	Budgets must cover high initial investments and operating costs while balancing cost and expected benefits with acquiring the right set of digital technologies.	*We still don't have the data to make the right choices and determine how we can reduce the costs for these kinds of technologies because the technologies are very expensive today*. (ID10)
	Sustainability	Substantial material resource investment must be balanced against expected technological benefits to support the sustainability goals of smart cities.	*I always question the [material] resource input. The robotic components must come from somewhere that indicates production effort. What happens to the IT afterward? If I just harvest a tomato by hand, that requires fewer resources.* (ID17)
Cultural readiness	Knowledge sharing	Openness to share knowledge and best practices of digital technology use are required to drive technological advancements in the entire market.	*You find out through partners where you can buy such an irrigation system and then build on the experiences of your neighbors.* (ID17)
	Trial-and-error mentality	A trial-and-error mentality is required to face the challenges of an immature market with little experience in best practices.	*In this area, there is very little experience, which is why s/he has to try everything by herself/himself to make things work.* (ID16)
	Culture of change	A culture of change is required to leverage the opportunities of a fast-paced industry.	*I also think sometimes we approach the topic from a traditional standpoint. That is the problem we have. I am very open to new and different approaches, and I believe other people have to share that.* (ID13)
	Transdisciplinary mindset	The corporate culture must unite perspectives from agriculture and IT to foster a transdisciplinary mindset, leveraging knowledge from both sides.	*We are not farmers, but we are all from a technological area. […] We, in contrast, do not have the experience and the intuition to see [the needs of plants] ourselves.* (ID12)

Readiness Category	**SUA Readiness Factor**	**Description**	**Exemplary Quote from Interviews** (ID of Practitioner)
	Appreciation	The workforce must understand the benefits of using digital technologies to continuously drive adoption and further developments.	*People need to understand how to use it. It's more high-tech than the traditional way of growing plants. People need to understand the values of these technologies and how to use them.* (ID10)
	Fun factor	The adoption of digital technologies is motivated by the perception that using them is a fun activity.	*It is easier for us [to use digital technologies] because we both work and are not always present with the farm animals. We do that as a hobby because it is fun. […] We mainly use technologies because my husband enjoys them and has a high technology affinity.* (ID18)
Strategic readiness	Stakeholder awareness	The entire ecosystem must be aware of the financial and sustainability-related benefits of SUA to foster trust and willingness to invest.	*This industry is really at the beginning of a long journey. It'll take a long time until we will have come up with economic benefits for those who will invest […]. Currently, people are not happy to jump over to invest. They prefer to invest in other stuff.* (ID10)
	Scale-up pace	Significant potential to rapidly scale up is required to leverage digital technologies once more stakeholders recognize the market's importance and more data becomes available.	*[It's] a fast, fast-evolving topic, which many firms are currently jumping onto.* (ID11) *Partially, just not enough data is collected. […] If it's going well, things are documented in an Excel sheet. Automatic data collection and the integration of analysis are rare, but this will increase.* (ID19)
	Scale	The necessary investment in, and potential impact of, the digital technology should be appropriate to the scale of the organization – particularly in the case of highly automated, high-tech systems – to fully leverage and drive profitability.	*We have three sizes [of products. …] The machine support and smart systems are more in the largest size. […] In a large farm, everything has to be optimized because the forklifts drive around, and it is very highly automized.* (ID16)

Readiness Category	**SUA Readiness Factor**	**Description**	**Exemplary Quote from Interviews** (ID of Practitioner)
Partnership readiness	High-tech supply availability	High-tech components that cannot be produced internally must be reliably available to uphold the operation of urban agriculture.	*So, in such cases, they are dependent on other external partners. It would be difficult to develop or operate the systems themselves. That's why they cooperate with tech companies*. (ID11)
	Personal network	Organizations must build strong networks of personal contacts to find the right suppliers of IT and components in a niche market.	*[The founder] has a large network with contacts for, for example, IT solutions from SAP, where he knows it is working well. [..] We use personal contacts as much as possible because it is working well for us.* (ID12)
	Ecosystem integration	Urban agriculture ecosystems must be closely connected to integrate perspectives from all actors (investors, farmers, communities) and not miss out on important knowledge.	*We are now seeing investors – bankers, machine engineers, different types of people – turning to smart urban agriculture. But the normal farmer who produces our food is left out. I, thus, see our responsibility to connect everyone.* (ID13)
	Training opportunities	Organizations looking to enable the operation of urban agriculture solutions in their ecosystem must ensure knowledge building and training in their external network.	*In total, there are multiple stakeholders that have to be introduced to the technologies in different locations.* (ID11)
Regulatory readiness	Adherence	Organizations must continually adapt to new regulations in the evolving market.	*Data security makes it more complex and difficult to bring out a legally compliant product.* (ID15)
	Laws	To enable benefits for smart cities, policymakers must adapt existing regulations – established with reference to traditional farming – to the new requirements of urban agriculture.	*Yes, still, in many countries, no developed policy makes it hard for farmers to grow this method. […] for example, in Israel, we don't have anything related to it, so you actually cannot build factories like that in Israel today unless you have a special agreement with the government to do it. […] For example, if a farmer grows lettuce, all of the regulation that gives him water subsidies are for the size of his land and for this specific plant.*

Readiness Category	SUA Readiness Factor	Description	Exemplary Quote from Interviews (ID of Practitioner)
			Let's say that someone builds a factory that grows lettuce. The law just counts how many square meters the factory is; even though the factory grows 400 times more crops per square meter, he will still get 1/400 of subsidies of water for this use. The laws are not really in line with the subsidies we should have for farmers. (ID10)

Table 17: Readiness Factors in Smart Urban Agriculture

5.4 Discussion

There is substantial evidence that digital innovation promising for mastering urban agriculture, e.g., by automizing tedious manual labor or reducing resource consumption during production (Langendahl, 2021). However, in practice, their potential is not yet leveraged. The fundamental challenge is that many of the emerging SUA endeavors fail economically – may it be due to high investment costs, lacking skills and talent in workforces, a wrong selection of technologies during implementation, or the inability to materialize the expected financial, environmental, and social benefits in the long run (Langendahl, 2021; Yigitcanlar et al., 2022). In respect to solving this challenge, our contribution is twofold.

First, we contribute a taxonomy that enables both research and practice to better understand what application possibilities "digital technologies in urban agriculture" comprise, and what differences exist between various types of SUA. Therein, we make use of the value of taxonomies which research in the IS community describes as (1) building the basis for conceptualizing a new phenomenon (i.e., SUA) and (2), a necessary step towards reducing research and practice's overload caused by the multitude of different SUA technologies available (Kundisch et al., 2022). We build on urgent calls from DT literature regarding the importance of enabling a conscious, well-informed adoption of digital technologies in order to reduce project failure (Hess et al., 2016; Riera & Iijima, 2019).

Second, discussing our results against the broader context of smart city and IT-enabled green city literature, we interpret our findings as an extension to existing studies in the field. On a general level, existing research recognizes the need for digital innovation in cities for a sustainable transformation (Dewi et al., 2018; Maye, 2019). However, the main focus currently

mainly lies on use cases related to democratizing governance, healthcare, sustainable housing, mobility, or education (Kinelski et al., 2022; Yigitcanlar et al., 2022). Acknowledging the importance of these areas, we argue for a stronger integration of smart urban farming within the smart city and IT-enabled green city literature streams, given the demonstrated potential of SUA. Complementing previous studies on related fields such as smart city readiness (Dewi et al., 2018; Yigitcanlar et al., 2022), the readiness factors in these studies directly address the challenge of financially failing SUA initiatives by providing a list of factors to consider during project launch.

However, the contribution of both the taxonomy and the readiness factors is not isolated, which is why we provide an integrative view of the findings from both perspectives, called "meta-inferences". They are summarized in Table 18. The presented 15 meta-inferences allow the disclosure of interrelations and boundary conditions of SUA's taxonomy dimensions and readiness categories.

Inference from Readiness Categories	**Inference from Taxonomy Development**	**Meta-Inference**	**Exemplary links to existing IS research streams**
Resource readiness	Digital technology	With the technological *functionality* of SUA reaching up to fully autonomous systems, the resource readiness factors of *IT expertise* and *IT infrastructure* become the backbone of SUA endeavors. While the resource readiness factors *finances* and s*ustainability* remain relatively stable across rising digital functionality levels, the importance of IT expertise and infrastructure readiness increases with technological maturity.	• IT capabilities research (e.g., Y. Chen et al., 2015; Nwankpa & Datta, 2017) • Maturity model research (e.g., Stoiber et al., 2023) • Data management research (e.g., R. Zhang et al., 2019)
Resource readiness	Data	With SUA's data *content* ranging from environmental parameters to the process interaction of individual SUA components, resource requirements include not only the acknowledgment of data as a valuable resource. Rather, SUA organizations must also build transdisciplinary data handling skills to understand technical and domain-specific data analysis activities.	
Resource readiness	Approach	The *types* of SUA range from those similar to traditional rural farming (e.g., ground open air) to highly innovative forms (e.g., vertical indoor), each requiring a different level of	

Inference from Readiness Categories	Inference from Taxonomy Development	Meta-Inference	Exemplary links to existing IS research streams
		technological resources. Given an organization with very low readiness level in respect to, for example, *IT expertise*, they should rather choose *supporter* classified SUA than *enabler*.	
Cultural readiness	Digital technology	Successful SUA endeavors require a culture supporting digital change. Given that SUA is drastically different from traditional rural farming, organizations need to build a culture that trusts the functionality of digital technologies and appreciates its benefits. How strongly the respective culture should be digitally focused depends on digital technologies' role as *supporters* or *enablers*.	• Digital change management research (e.g., Salmimaa et al., 2018) • Technology acceptance research (e.g., Venkatesh, Thong, & Xu, 2016)
Cultural readiness	Data	As new data sources emerge that must first be meaningfully combined and analyzed, a culture of learning is required. Given that employees can even act as the data *source* in agent-related sensing, a higher awareness for the value of data and its generation needs to be achieved.	
Cultural readiness	Approach	It is not enough to build a generally tech-savvy culture because an important part of cultural readiness is to understand the benefits of digitalization in the respective work context. The *type* of SUA implicates the different possibilities of digital technologies and culture-building activities must refer to its specific value for each type.	
Strategic readiness	Digital technology	SUA and its two *roles* bring out digital technologies' dual nature. Digital technologies serve as (1) a facilitator of new value propositions as an integral part of the end product and (2) a lever for scaling existing solutions more efficiently through technological characteristics such as convergence and generativity.	• Digital social innovation research (e.g., Qureshi et al., 2021) • Twin transformation research (e.g., Graf-Drasch et al., 2023) • Data-oriented perspective for addressing sustainability
Strategic readiness	Data	As SUA approaches are in their infancy, strategies must build on available data (e.g., machine and interaction data) and be designed to adapt quickly to new data and sources. Therein, data plays a leading role in developing profitable business	

Inference from Readiness Categories	Inference from Taxonomy Development	Meta-Inference	Exemplary links to existing IS research streams
		models and can determine the success of SUA.	issues (e.g., Melville et al., 2017; Zampou et al., 2022)
Strategic readiness	Approach	An urban agriculture organization must choose wisely which *type, end product* and *nutrient medium* to implement as those parameters have implications on the *scale*, *scale-up pace* and *stakeholder's acceptance*. For example, *plants* cultivated vertically in *air* or *water* are easier to scale-up efficiently in cities but require a lot of persuasion beforehand for stakeholders to trust those new endeavors.	
Partnership readiness	Digital technology	Many SUA solutions are complex and highly automated systems, representing niche products due to the nascent market. This is a particular challenge in cases where SUA technologies take the role of *enabler* and are crucial for keeping the urban agriculture organization going. SUA stakeholders depend on a solid network and strong partners to jointly develop individual solutions. However, there are no standard solutions available on the market.	• Green IS/IT research (e.g., Gholami et al., 2016; Malhotra et al., 2013; Watson et al., 2010). • Digital ecosystems research (e.g., Adner, 2017; Hannah & Eisenhardt, 2018). • Data sharing research (e.g., Melville et al., 2017; Zampou et al., 2022)
Partnership readiness	Data	The different *sources* of data can most likely not all be provided by a SUA organization itself. Especially in the case of air-based data, there is a high dependency on growing not only one's own SUA organization but also simultaneously the competitive market providing relevant air-based data points for operation.	
Partnership readiness	Approach	Partnerships in SUA are diverse and can range from traditional farming companies providing crops to high-tech software firms. As a result, depending on the *type* and *end product*, SUA organizations must learn to build networks that deal with and leverage the diversity of required connections.	
Regulatory readiness	Digital technology	Integrating various digital technologies differing in functionality or design (such as *interfaces*) also poses new regulatory	• AI research on ethical decision-

Inference from Readiness Categories	Inference from Taxonomy Development	Meta-Inference	Exemplary links to existing IS research streams
		concerns. Depending on the technologies selected, topics such as the ethical use of AI or prevention of digital stress/technostress and work accidents with robotics emerge as new tasks for SUA endeavors.	making and responsibilities (e.g., Mikalef et al., 2022) • Data privacy and protection research (e.g., Cichy et al., 2021) • Intersection of IS and policy (e.g., Watson et al., 2022)
Regulatory readiness	Data	New regulations are required, with the emergence of new data giving rise to increased transparency and traceability related to food security and the climate status of cities. Simultaneously, existing regulatory requirements on data protection and security must be fulfilled, which is especially relevant in the case of employees as *data sources*.	
Regulatory readiness	Approach	The regulatory framework of SUA is still evolving. When integrating SUA approaches into cities, there may be a mismatch between suitable business models and rigid policy regulations. For example, while a vertical farm or the integration of animals might be the best solution for an organization to provide food security in a city, regulations might not support this *type* and *end product* of urban agriculture.	

Table 18: Integrative Meta-inferences for Smart Urban Agriculture

The complementary perspectives on SUA reveal relevant findings on the intersection of taxonomic research and readiness research, as presented by the meta-inferences. In addition, in order to explain how the two perspectives inform each other on a practical level, we illustrate two use cases below: Considering two examples of SUA at the extremes of the different solutions' spectrum, we take (1) a high-tech industrial vertical farm, and (2) a miniature greenhouse for private balconies as the baseline. Looking at the taxonomy, use case (1) would be classified as an enabler, with digital technologies being the backbone of the solution, technological functionality reaching to autonomous adaption, external interfaces being available at multiple touchpoints, process and environmental data being integrated, and different nutrient mediums used, depending on the specific end product. Use case (2), in contrast, includes some smaller technological components as a supporter to give

recommendations on when to water the plants, integrates a few data points on soil moisture, and a small solution-integrated display.

In terms of the relevance of different readiness factors depending on the taxonomic classification, our results summarize to several interpretations. While *resource readiness* is generally highly relevant to both use cases (1) and (2), the factors concerning *IT expertise* and *IT infrastructure* are more relevant to (1) high-tech *enabler* industrial vertical farms than (2) small private *supporter* SUA, as private consumer solutions are often stand-alone and intuitive to use. For *cultural readiness*, themes regarding openness to change are critical for use case (1), where the respective SUA solution is often not selected by the employees but by management. In contrast, in use case (2), the *fun factor* is predominant as motivation to decide on a SUA by oneself and to continue using it after its implementation, as no monetary incentives such as salaries are present. Lastly, regarding *regulatory readiness*, the requirements also strongly differ, depending on the selected *approach* and type of urban agriculture. For use case (1), existing policies and their *adherence* are critical but simultaneously highly complex, given the many different regulatory concerns on food safety, employee rights, subsidy opportunities, or trade permits. A lack of adherence to such regulations bears the risk of both legal and reputational damage. For use case (2) and private ground indoor approaches, few regulations on balcony usage might also exist. However, private endeavors are mostly free to choose what to do with their own living space, making this readiness category less critical.

Summarizing, the readiness factors differ in relevance depending on the selected use case. Major differences emerge regarding the type of organization (e.g., small private versus large-scale professional endeavors), the technological advancement degree, and the approach selected. The visualization of the two use cases above does not claim comprehensiveness regarding the differences in the relevance of organizational readiness factors depending on SUA type. Rather, it demonstrates how classifying different SUA solutions and their underlying organization type through our taxonomy informs the relevance of the different readiness factors.

Theoretical Implications

Summarizing the discussion above, a deep understanding about the contextual implications of digital innovation outcomes in SUA is required to unfold and leverage its full potential. Theoretical implications to both the broader literature on taxonomy development and readiness are threefold.

First, and in line with existing taxonomic IS research (e.g., Addas & Pinsonneault, 2015; Böttcher et al., 2023), our taxonomy offers a common ground for conceptualizing the scattered nature of SUA outcomes by uniting terms from various domains and generalizing subtypes, as well as delivering high levels of knowledge regarding the possibilities for applying digital technologies to urban agriculture. In doing so, we build on prior taxonomic research that can be assigned to the research domains of either smart farming, or smart city and IT-enabled green city. First, we extend smart farming taxonomies (e.g., Balafoutis et al., 2017) by referring to urban rather than traditional, rural farming contexts, and viewing smart agriculture from a BISE rather than from an agricultural or bio-economic perspective. Second, we extend smart city taxonomies analyzing various smart city projects and digital technologies (e.g., Perboli & Rosano, 2020) by focusing on the urban agricultural sector. The provided classification scheme and thus demonstration of the scope of SUA serves as a starting point for theorizing: According to Gregor (2006), a taxonomy is a "theory for analyzing"; the most basic type of theory that describes and classifies by summarizing the commonalities in discrete observations. It enables the grouping of digital technologies in urban agriculture, allowing for relationships between the different groups to be hypothesized and tested. With our taxonomy, future researchers in this area do not have to analyze each SUA solution individually but can directly assess groups of such solutions. Our taxonomy helps to initiate and develop SUA innovations by offering the basis for more generalizable insights on digital technologies in urban agriculture.

Second, the identification of 20 SUA specific readiness factors provides theoretical understanding at the intersection of emerging literature on smart city and smart farming readiness (Dewi et al., 2018; Yigitcanlar et al., 2022). Some readiness factors directly build on previous research in smart farming (e.g., lack of data standards, or a deficit of digitally-savvy workers; Giua et al., 2021; Knierim et al., 2018) and smart city research (e.g., high connectivity through physical infrastructure, standards and interoperability; Dewi et al., 2018; Yigitcanlar et al., 2022). In addition, a few new, SUA-specific readiness factors emerge. This includes, for example, factors of the category *strategic readiness* with *scale-up pace* and *scale* or categories such as *regulatory readiness* with *adherence* and *laws*. In terms of their contextualization, regulatory readiness is especially relevant in the SUA domain, because the shift from a long-standing traditional industry (i.e., farming) into the digital and urban realm brings massive changes to legal requirements. Second, readiness factors related to partnerships and strategic directions are particularly relevant in this context because of the novelty of SUA and the resulting lack of existing network partners. Overall, for the successful adaption of various SUA

endeavors, some readiness factors are always relevant and important (e.g., *IT expertise* and *IT infrastructure*) while others play a less significant role (e.g., *appreciation* and *fun factor*). The readiness factors contribute to theories on opportunity exploitation and organizational readiness by offering a concrete list of factors relevant to the successful exploitation of SUA and potentially other domains (Kreuzer et al., 2022).

Third, by integrating the taxonomy and readiness factors through meta-inferences, we offer a theoretical lens for theorizing on the relationship between IS and urban agriculture as a particular instantiation thereof. In that regard, this chapter also answers questions posed by prime IS outlets asking how associated artifacts may foster more sustainable development (e.g., Gholami et al., 2016; Watson et al., 2010). Overall, the three central themes emerging from the meta-inferences comprise (1) the need to jointly build a business ecosystem around SUA technologies in order for all partners to succeed, (2) the significant differences in project execution depending on the level of technification, and (3) the role of the social side – i.e., the development of skills and digital culture. For research, these results pinpoint relevant avenues for further advancing SUA knowledge, for example by analyzing the ecosystem dynamics in SUA or capabilities needed for SUA initiatives.

Practical Implications

Our results are meant to address all stakeholders aiming to leverage SUA's value: Professional urban agriculture organizations, housing associations, public administrations (e.g., city planners), or individual homeowners.

From the perspective of different actors involved in implementing SUA endeavors, the results will help plan and maintain SUA endeavors. The set of 20 readiness factors guides the actors in planning urban agriculture endeavors by providing a checklist of factors to consider before digital technology implementation. While fulfilling all readiness factors cannot ensure a success rate of 100%, it can reduce failure caused by financial troubles or lack of capabilities by increasing readiness. To name just two of the actionable suggestions following from our readiness factors, the factors *appreciation* and *trial-and-error mentality* (cultural readiness) serve as suitable illustrations. First, appreciation suggests that smart urban farmers actively communicate the value and benefits of the planned endeavor to the entire workforce to drive its acceptance. As a core component of successful change management, such communication needs to be included in the decision-making on the exact timeline of SUA endeavors to drive appreciation. Second, the readiness factor on trial-and-error mentality implies that smart urban

farmers need to assess their current culture on the readiness to experiment. In case of low experimentation levels, the factor implies the need to increase experimentation through initiatives such as experimental laboratories or dedicated time for experimenting.

For policymakers, the regulatory readiness factors are also a call to develop regulations that reflect smart urban agriculture's peculiarities. Specifically, in terms of *adherence* to existing laws, policymakers need to closely monitor that data protection regulations are adhered to, as data is becoming increasingly important in smart (urban) agriculture. Concerning new laws and subsidies, our results are meant to motivate policymakers to develop appropriate tools for incentivizing sustainable practices in urban agriculture. This could include subsidies on the acquisition of high-tech soft- and hardware, machinery, or buildings (in the case of indoor vertical farming).

Finally, moving from individual actors to the portfolio of stakeholders representing a city, our results offer initial inspiration for integrating SUA in cities. Smart cities are a crucial prerequisite to attaining the UN's Sustainable Development Goal number 4, "Sustainable Cities and Communities" (United Nations, 2015). Cities striving to increase biodiversity, rewild, or use green spaces as carbon emission storage and food source, can use our taxonomy to review different urban agriculture approaches and identify potential use cases of digital technology through the proposed dimensions. Thus, users may find inspiration for SUA endeavors or increase their awareness of how digital technologies can improve cities beyond mere energy efficiency.

Limitations and Future Research

This chapter has some limitations and highlights avenues for future research. Firstly, the evaluation sample of 32 real-life SUA technologies serves as a good starting point, as it comprises a wide variety of digital technologies. However, this sample does not represent a full market overview. As the industry matures and comprehensive databases of such digital technologies emerge, an extended demonstration using more real-life examples will become necessary to validate our initial findings and draw conclusions on the distribution of examples across characteristics. Secondly, we interviewed practitioners from Austria, Germany, Israel, and the Netherlands. While this sample covers different regions, it does not represent the global SUA industry. It would be interesting to assess local differences in SUA readiness, such as policies and regulations, resources, and skills, via a larger sample of interviews.

The results yield interesting pathways for future research in the IS community. Currently, the process of farmers' evolution from urban to smart urban is unknown. Becoming a SUA champion will not be a binary process from 0 to 1 but will involve various stages of development. For research and practice to understand this process, the development of a maturity model of SUA – including the readiness factors for each stage (e.g., readiness levels) – is a research endeavor that promises to strengthen conceptual understanding of the topic (Linhart et al., 2017).

Future investigations may also quantify the specific gains triggered by digital innovation in SUA contexts, to better explicate its value. Empirical research, for example, could conduct field studies that compare the outcome of different urban agriculture approaches – with and without digital innovation. Results may differ in terms of environmental sustainability (i.e., energy savings, efficiency of resources), societal (i.e., facilitation of work effort) and technical gains (i.e., creation of data sources, data transparency, monitoring and prediction options) or economic profitability. Similarly, future research can evaluate differences in gains based on the individual SUA dimensions and characteristics.

Conclusion

Mindful of the grand sustainability challenges we grapple with, they may constitute a "window of opportunity" for new organizational innovation endeavors. We propose a multi-layer taxonomy that characterizes digital innovations helping to leverage sustainability opportunities in urban agriculture and suggest 20 organizational readiness factors for smart urban agriculture as a starting aid. Our work contributes to digital innovation for sustainability research by providing a structuring tool for innovation outcomes in the urban agriculture realm. Overall, this chapter sets the scene for a thorough conceptual understanding of the nature of SUA innovations and requirements for leveraging their value.

6 Research Agenda for Digital Social Innovation

The previous chapters outline the potential of digital innovation for sustainability along the digital innovation actions, environments, and outcomes. Digital innovation for sustainability is an umbrella term spanning many individual research streams across disciplines, such as Green IS or digital eco-innovation (Butler & Hackney, 2015; Carberry et al., 2019; Joukhadar et al., 2023). While the two examples focus exclusively on environmental sustainability, the emerging research stream on digital social innovation integrates all three pillars of sustainability (Buck, Krombacher, et al., 2023). The following chapter expands on the potential of DSI and conforms with (Graf-Drasch et al., 2022) for most parts.

DSI stems from the synthesis of digital innovation and social innovation (Buck, Krombacher, et al., 2023). In contrast to digital innovation, social innovation refers to innovation activities that comprise economically viable ideas to primarily create social value, addressing societal challenges across all the pillars of sustainability (Tracey & Stott, 2017). Originating from the perspective that profit orientation at the expense of social and environmental well-being is morally reprehensible, social innovators have proved that the potential of innovation could also drive sustainable development (Dacin et al., 2011). For example, social innovation includes initiatives around fostering education or developing a new strategy for facilitating the funding of charity projects (Battistella et al., 2021). Social innovation, however, has not yet comprehensively acknowledged the potential of digital technologies. So far, both valuable research streams (i.e., digital innovation and social innovation) coexist mostly separated without leveraging the synergies at their interface. We are convinced that the exceptional value of both streams for targeting sustainability is greatest at the intersection of the generative power of digital innovation and the social value creation from social innovation. Thus, we aim to join forces of both research streams advancing research on *digital social innovation*, understood as "digital solutions to social challenges" (Bria, 2015, p. 4).

DSI is a relatively new phenomenon and most studies that mention the term were published in the last few years (e.g., Bonina, López-Berzosa, & Scarlata, 2021; Buck, Krombacher, et al., 2023; Gebken et al., 2021; Mehmood & Imran, 2021; Qureshi et al., 2021). Scholars have started to discuss DSI as an integrated concept recently and discuss, for example, its potential for certain facets of sustainable development (e.g., Suseno and Abbott (2021) for gender equality) or topics such as participation motives in DSI (Rodrigo & Palacios, 2021). However, there exists additional literature on the intersection of digital innovation and social innovation

with valuable insights, which is currently less present because of inconsistent terminology. Existing DSI research is highly scattered across disciplines, outlets, and terminologies, making it difficult to grasp the richness of prior contributions. However, a synthesis of prior contributions on DSI across innovation actions, environments, and outcomes would help to bring forward the research stream. Therefore, it is essential to understand the (1) different dimensions of DSI, (2) existing contributions, and (3) critical research pathways and their implications for DSI. Such an integrated understanding is crucial to creating a common ground on DSI for advancing future knowledge quickly (Webster & Watson, 2002). Our research question thus reads:

What are critical DSI research pathways?

To answer the research question, we bring together the research streams of digital innovation and social innovation, building upon a theory-based multidimensional framework for analyzing existing DSI literature identified through a systematic literature review (Boell & Cecez-Kecmanovic, 2015; Leidner, 2018; Webster & Watson, 2002). We identify relevant dimensions of DSI to structure and capture both well-researched themes and critical paths for future research to derive a research agenda. We discuss the research agenda with 10 scholars at the intersection of digital technologies, innovation, and sustainability to sharpen its implications. Therein, we build six research clusters across and derive 12 critical research pathways for IS scholars.

6.1 Theoretical Background

DSI uses digital technologies to address societal challenges (Bonina, López-Berzosa, & Scarlata, 2021). DSI draws knowledge from digital innovation with an integral part being digital technologies and the sustainability orientation of social innovation. Table 19 displays recent definitions in the IS domain, which allow for different interpretations as scholars build on and combine the concepts of digital technologies, digital innovation, and social innovation differently (Bonina, López-Berzosa, & Scarlata, 2021; Buck, Krombacher, et al., 2023; Dong & Götz, 2021; Qureshi et al., 2021; Tim et al., 2021). To identify and structure current research on DSI and derive a research agenda we develop a theory-based multidimensional analysis framework consisting of the dimensions (1) *digital innovation*, (2) *digital technology*, and (3) *social innovation*. Following, we elaborate on all three dimensions.

Source	Definition
Qureshi et al. (2021, p. 647) based on Qureshi et al. (2017) and Shalini et al. (2021)	"Digital social innovation (DSI) involves the **use of digital technologies** in the development and implementation of innovative products, services, processes, and business models that seek to improve the well-being and agency of socially disadvantaged groups or **address social problems** related to marginality, inequality, and social exclusion."
Tim et al. (2021, p. 324) based on Majchrzak et al. (2016) and Pan and Zhang (2020)	"Digital social innovation (DSI)—the **novel use of digital technology to address major societal challenges**—has been the bedrock of sustainable development and has therefore garnered increasing attention amongst researchers and practitioners particularly in recent years."
Bonina, López-Berzosa, and Scarlata (2021, p. 698)	"[…] we define DSI broadly as the development of new products, services or processes, that are either **embodied on IT or enabled by IT**, whose goal is to **meet social needs or stimulate social change**."
Dong and Götz (2021, p. 673)	"Open source software (OSS) is a typical digital social innovation […] OSS is a **combination of digital innovation and social innovation**, or digital social innovation."
Buck et al. (2023, p. 4) based on Bonina, López-Berzosa, and Scarlata (2021)	"In the context of incumbents, we define DSI as the **leveraging of digital technologies to address societal challenges through commercially viable innovation.**"

Table 19: Definitions of Digital Social Innovation

First, regarding the *digital innovation* dimension, Subchapter 2.1 presents a detailed overview of existing research. To structure previous insights in line with digital innovation for sustainability knowledge generated in this dissertation, we assess the digital innovation dimension through the characteristics of innovation (1) actions, (2) outcome, and (3) environment (Kohli & Melville, 2019).

Second, regarding the *digital technology* dimension, digital technologies comprise different loosely coupled layers, i.e., device, network, service, and content (Henfridsson et al., 2018; Yoo et al., 2010). To date, the boundaries and scope of digital technologies have not been clearly defined, and the term is often used interchangeably with the notions of IT, IS, and ICT. ICTs are tools that enable communication and collaboration, such as smartphones or tablets (Dittes & Smolnik, 2019; Zuppo, 2012). Overlapping with ICTs, digital technologies are described as a combination of connectivity, information, computing, and communication technologies (Bharadwaj et al., 2013) using digital resources to acquire, create, analyze, or communicate information in specific contexts (Zuppo, 2012). Further, digital technologies are understood –

more vaguely – as an umbrella term for IT within the context of digitalization (Denner et al., 2018). With respect to digital innovation, digital technologies can assume two different roles: (1) they can be applied during the innovation process itself (i.e., *digital technologies as a means*) and (2), they can be part of the innovation outcomes (i.e., *digital technologies as an end*) (Ciriello et al., 2018; Nambisan et al., 2017). Thus, as a means refers to digital technologies supporting the development of new solutions (e.g., using digital platforms to connect people to co-create innovative solutions) and therefore, the outcome of the innovation process can be digital, hybrid, or non-digital (Ciriello et al., 2018; Nambisan et al., 2017). As an end refers to the digital technology being part of the digital (or hybrid) innovation outcome (e.g., a new mobile application) (Ciriello et al., 2018; Yoo et al., 2010). To fully capture the role of digital technologies in DSI, we thus differentiate between the two characteristics (1) digital technologies as a means of DSI or (2) digital technologies as an end to DSI.

Third, regarding the *social innovation* dimension, a plethora of non-technological research streams has engaged in social topics at the intersection of innovation. Corresponding knowledge has emerged on sustainable innovation, eco-innovation, green innovation, environmental innovation, responsible innovation, frugal innovation, and social innovation (Albert, 2019; Alraja et al., 2022; Franceschini et al., 2016; Lubberink et al., 2017). Further, scholars have examined IS in social contexts without emphasizing an explicit innovation-focus, resulting in dedicated research streams such as ICT4D (i.e., ICT for Development), Green IS, or social tech (Arena et al., 2018; Tarik et al., 2021; Walsham, 2017; Watson et al., 2010). DSI focuses on using digital technologies to lever social innovation. Therefore, digital technologies enable diverse applications within the social domain, such as using e-commerce to alleviate poverty (Tim et al., 2021) or reducing high infant mortality through digital technology intervention (Venkatesh, Rai, et al., 2016). Social innovation aims at creating social value, i.e., "the creation of benefits or reductions of costs for society – through efforts to address social needs and problems – in ways that go beyond the private gains and general benefits of market activity" (Phills et al., 2008, p. 39). Thus, we incorporate societal needs in social innovation as the third dimension of our analysis framework, including improving human and environmental well-being (Lubberink et al., 2017). An innovation is classified as a social innovation when its underlying rationale attains social instead of purely economic goals (Phills et al., 2008). Today, interpretations of social innovation are generally broad and address different societal needs. Thus, social innovation is often associated with attaining the SDGs (Eichler & Schwarz, 2019). As presented in Subchapter 2.2, the SDGs comprise 17 sub-goals spanning from social (e.g.,

Good Health and Well-being) over environmental (e.g., Life on Land) to economic sustainability (e.g., Decent Work and Economic Growth) (J. Wu et al., 2018) or in other words people, planet and profit (Palmer & Flanagan, 2016). All three sustainability dimensions are subsumed through the concept of sustainable development and target the protection of natural resources (i.e., planet) and providing social and economic welfare (i.e., people and profit) (WCED, 1987). On this background, our analysis framework captures the three sustainability dimensions addressed by social innovation through the characteristics (1) people, (2) planet, and (3) profit. We consciously make use of the notion of people, planet, and profit to avoid any confusion between the digital innovation environment and the environmental sustainability pillar.

For this chapter, we integrate the three dimensions (digital innovation, digital technology, social innovation) to assess prior contributions according to the core components of DSI and derive a DSI research agenda. Figure 22 depicts the resulting analysis framework.

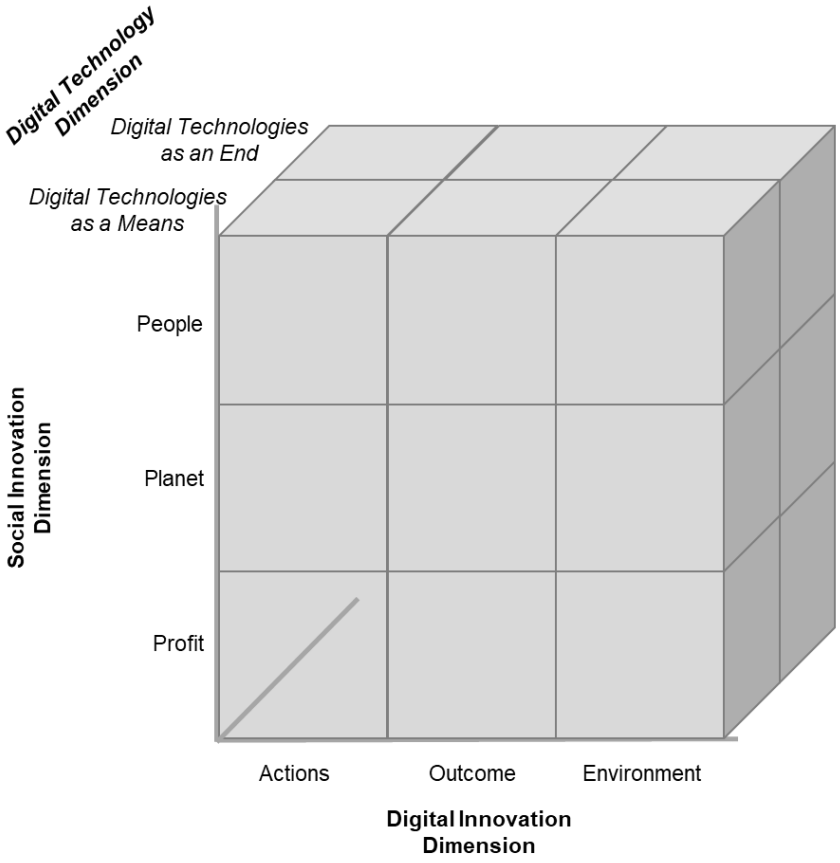


Figure 22: Digital Social Innovation Analysis Framework

6.2 Research Methodology

To derive meaningful research pathways for DSI, we conducted a two-phase research approach. We first used the analysis framework presented above to synthesize existing DSI contributions, uncover research gaps, and derive a research agenda worth investigating (Leidner, 2018; Webster & Watson, 2002). Next, we conducted 10 expert interviews with IS scholars in the DSI domain or in one of the intersecting areas (e.g., digital innovation) to expand, discuss, and challenge the literature-based research agenda in an iterative manner (Myers & Newman, 2007). Figure 23 shows the overall methodological design of this chapter.

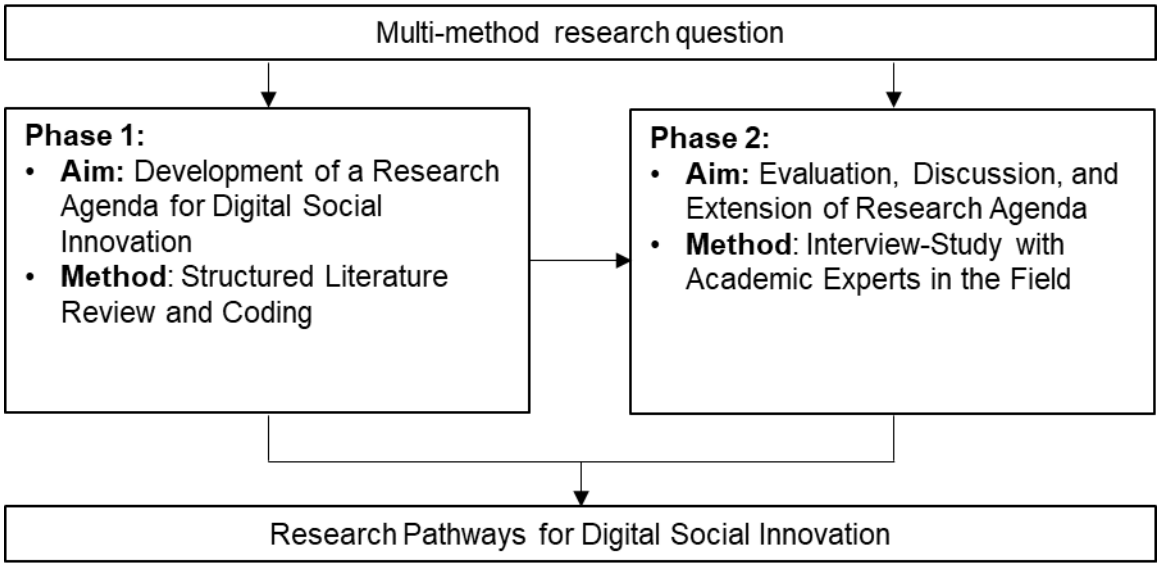


Figure 23: Two-phase Research Approach for Digital Social Innovation

Phase 1: Initial Development of Research Agenda

For phase 1, based on Leidner's (2018, p. 1) "polylithic framework of research and theory development papers", we classify our literature review as an "assessing review" with the research objective to synthesize literature and the review focus to identify gaps. Specifically, we conducted a systematic DSI literature review following Boell and Cecez-Kecmanovic (2015) alongside five-steps detailed in Figure 24.

(1) Define Search Protocol: We selected literature bases covering both IS and other fields. For IS, we focused our search on high-impact IS journals and conference publications, i.e., the Senior Scholars' List of Premier Journals (Association for Information Systems, 2023), the International Conference on Information Systems, the European Conference on Information Systems, the Americas Conference on Information Systems, and the Pacific Asia Conference

on Information Systems. The conferences are included to address the trade-off between the topicality of DSI and longer review cycles in top journals in comparison to conferences. For the other fields and to cover the whole picture of DSI in other disciplines, we additionally used the database Web of Science. Within Web of Science, we searched journals across disciplines with an impact factor higher than 2.5 to ensure a high-quality sample. This criterion is in line with Henkel and Kranz (2018) and a popular numerical measurement method in scientific work (Garfield, 2006). While Garfield (2006), creator of the Social Science Citation Index, acknowledges that the journal impact factor is not a flawless measure, he argues that it is well established and that a superior metric remains to be found. Typically, an impact factor larger than 3.0 is conceived as a good threshold (Sci Journal, 2020). A factor of 3.0, however, would exclude relevant sustainability-focused journals. We, therefore, reduced the threshold to 2.5 to capture valuable contributions.

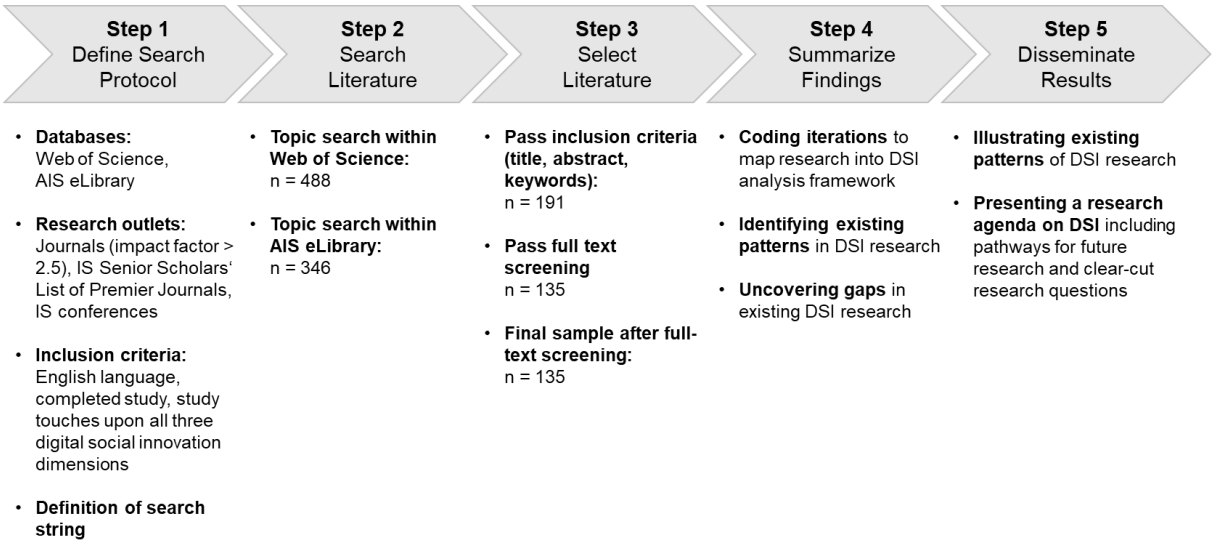


Figure 24: Five-Step Literature Review Approach as Proposed by Boell and Cecez-Kecmanovic (2015)

We defined our search string, focusing on relevant DSI contributions while simultaneously yielding the largest possible set of relevant studies. Accordingly, we derived three search strings consisting of multiple terms related to the DSI dimensions, as summarized below:

(1) (ICT4D or "Green IS" or "social tech") AND innovation*

(2) ("digital* innovation*" OR "ICT innovation*" OR "information technolog* innovation*" OR "information system* innovation*") AND (social OR sustain* OR green OR environmen* OR responsib* OR eco* OR frugal)

(3) ("social innovation*" OR "sustainab* innovation*" OR "green innovation*" OR "environmen* innovation*" OR "responsib* innovation*" OR "eco-innovation*" OR

"eco innovation*" OR "frugal innovation*") AND ("digital technolog*" OR ICT OR "information technolog*" OR "information system*")

DSI is an emerging phenomenon in many academic disciplines and is characterized by inconsistent terminology use (e.g., social innovation, sustainable innovation, green innovation, frugal innovation). We reflect this diversity in our search strings, which capture the diversity of all three dimensions.

(2) Search Literature: We conducted a literature search across Web of Science and the AIS eLibrary. The initial search yielded 834 results (488 studies in Web of Science and 346 studies in the AIS eLibrary), excluding duplicates and all studies from journals with an impact factor lower than 2.5.

(3) Select Literature: In a first relevance check, we screened the titles, abstracts, and keywords of the 834 studies (vom Brocke et al., 2015). Studies included (at least partly) address the outlined DSI dimensions. Further, a study had to be both composed in English and be a completed research study. To ensure uniformity in screening, three authors screened a sample of 20 studies independently. The three authors agreed in 19 cases and disagreed in one, leading to a high agreement level of p_0=98.41%. The remaining studies were split among two authors and screened independently. To dissolve potential ambiguities, all authors met in regular workshops. After the first screening, 191 studies remained for a full text screening. We analyzed the respective studies and evaluated whether they appropriately address all three defined dimensions of DSI. As a result, 135 studies remained. A list of the final set of studies as well as the integrated studies' domains can be found in Appendix F.1.

(4) Summarize Findings: To address our research question and identify pathways for further research, we investigated the contributions of prior work and developed a research agenda from the questions left open. We coded the final 135 studies using coding techniques of Stock et al. (1996) and Wolfswinkel et al. (2013) as an orientation. We read each study in detail during coding and assigned pre-defined characteristics grounded in the existing literature. These characteristics reflected the three DSI dimensions, i.e., digital technology (characteristics: as a means, as an end), digital innovation (characteristics: actions, outcome, environment), and social innovation (characteristics: people, planet, profit). Further, we grouped the studies to form research clusters alongside the postulated analysis framework. Studies in the same cluster resembled in DSI characteristics (per dimension) and study purpose. While assigning the characteristics, we found meta-insights regarding the dimensions, which we summarized and

further developed into pathways for further research. We refined the contents of each cluster until theoretical saturation was reached, i.e., while re-reading studies, no new insights to the clusters appeared, and we did not add new findings. Two co-authors each coded the articles independently to ensure high coding quality, and the results were discussed in regular author workshops. In terms of coding, we achieved an average agreement of p_0=0.7857 and a 'substantial' to 'moderate' (Landis & Koch, 1977) inter-rater reliability (Cohen's kappa) between 0.8128 and 0.5216 (overall average: 0.7061, median: 0.7982) per dimension (Cohen, 1960).

(5) Disseminate Results: We compiled and illustrated our results along with the outlined DSI analysis framework. The framework depicts existing research patterns in DSI research and helps uncover relevant gaps and pathways for further research. Moreover, we built on the findings from the six DSI research clusters to derive a research agenda for DSI based on a set of twelve research pathways.

Phase 2: Evaluation of Research Agenda

Phase 1 yielded a research agenda for DSI based on the rich literature published across domains. In the second phase, we proceeded to discuss, extend, and refine the initial version through expert interviews. The incorporation of expert interviews within the research methodology aims to deepen the understanding of the subject matter and enrich the literature review. In the IS literature, interviews are a well-known approach to evaluate qualitative research (Myers & Newman, 2007). As our research pathways are targeted towards a theoretical contribution, we conducted 10 semi-structured interviews with IS scholars in the DSI domain or in one of the intersecting areas. Thus, the expert interviews augment the literature review by providing firsthand insights, perspectives, and a nuanced understanding from individuals actively engaged in the field. The interviews aimed to complement existing scholarly knowledge, identify gaps or discrepancies in the literature, and offer valuable input for refining the research framework. We report on corresponding details in the following.

The selection of experts was done by a purposive sampling approach (Campbell et al., 2020), wherein individuals with extensive experience and expertise in the research domain were identified and invited to participate. The selection criteria encompassed criteria such as academic credentials, research contributions, and practical experience relevant to the research focus. To ensure diversity of perspectives, experts from various career stages, including PhD students, postdoctoral researchers, and faculty members, were included in the sample. Scholars

were selected based on their research focus and their academic position, creating a diverse set of interviewees. Appendix F.2 presents a detailed overview of the experts interviewed.

We conducted semi-structured interviews with each expert that lasted approximately one hour (Myers & Newman, 2007). Each expert interview followed a semi-structured format (see Appendix F.2 for the interview protocol) designed to facilitate in-depth exploration of key themes and topics pertinent to the research objectives (Myers & Newman, 2007). The interview protocol included open-ended questions addressing both broad conceptual issues and specific research inquiries. This structure allowed for flexibility in responses while ensuring consistency across interviews. All interviews were conducted digitally using Microsoft Teams and were accompanied and recorded by at least one co-author. After each interview, the experts' feedback was discussed within the author team. Following Gregor (2006) and Sonnenberg and vom Brocke (2012), we refer to completeness, understandability, and simplicity as criteria for evaluating the research pathways. The integration of interview insights into the research findings was guided by a process of triangulation, whereby interview data were compared with existing literature. The decision to integrate or challenge literature review findings was based on the extent to which interview insights provided additional depth, clarification, or divergence from existing knowledge and discussed by the author team. Overall, the experts confirmed that the research pathways were easy to understand and helpful for further research. They considered the research pathways relevant to address the challenges of DSI. With the help of the interviews, we gained important input for the gradual refinement of the research pathways. Appendix F.3 comprises a detailed list of the interview feedback incorporated in our research agenda.

6.3 Research Clusters of Digital Social Innovation

To extract a research agenda for DSI, we first have to understand prior contributions in a structured way. Therefore, we classified the 135 studies according to the three DSI dimensions and their respective characteristics as highlighted in Subchapter 6.2. For further analysis, we extracted six research clusters (Figure 25).

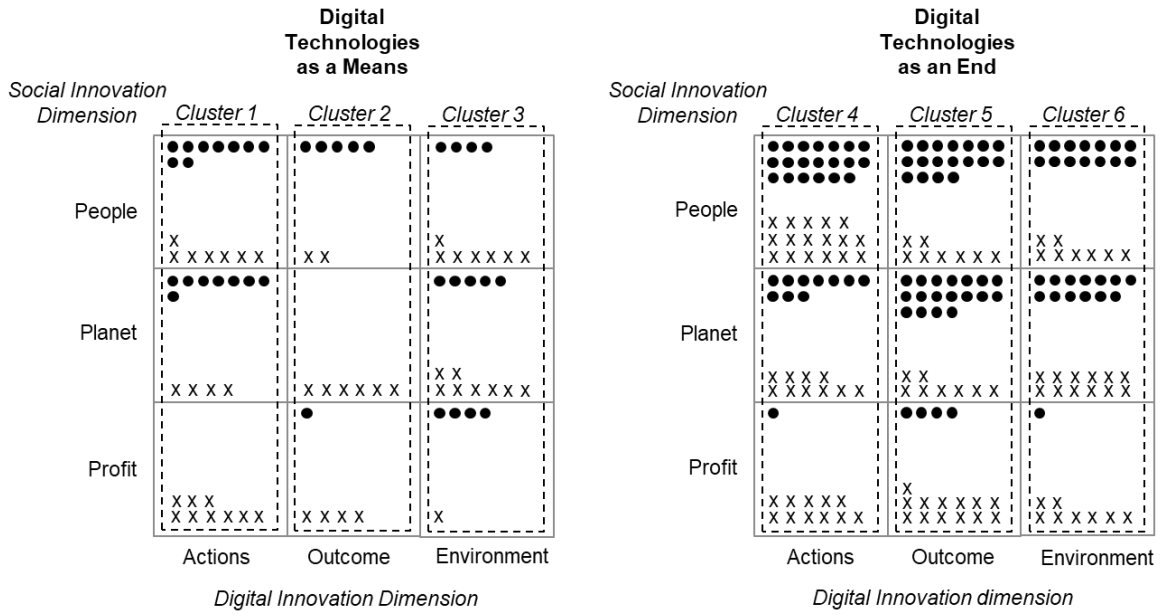


Figure 25: Digital Social Innovation Clustering Results

First, we split the dimensions according to digital technologies as a means and digital technologies as an end. Second, we differentiate between DSI actions, outcome, and environment. The six possible combinations of these two dimensions form the six research clusters. Third, within each cluster we further differentiate between people, planet, and profit. To visualize the distribution of studies across the clusters, Figure 25 also demonstrates the numerical results. Each dot represents the focus (i.e., 1st order) of a study in our sample. If a study peripherally touched upon a second characteristic (for example, the focus is on the DSI outcome, but a small part also considers DSI environment), we plotted an "x" in the respective field. From the total of 135 studies, 36 (27%) consider digital technologies as a means and 99 (73%) as an end. Further, 48 (36%) studies investigate DSI actions, 46 (34%) DSI outcomes, and 41 (30%) DSI environments. Lastly, 70 (52%) studies address people, 54 (40%) planet, and 11 (8%) profit. In the following, we discuss each cluster in detail, outlining exemplary contributions.

Research Cluster 1 – Digital Technologies as a Means and Actions: The first research cluster concerns studies that deal with innovation actions making use of digital technologies during the innovation process. Research activities in cluster 1 center on DT-enabled DSI actions. The two central themes are (1) leveraging data-based insights during DSI actions through data analytics (e.g., Kelly & Noonan, 2017), and (2), fostering broad stakeholder involvement for DSI actions through digital platforms and tools (e.g., Ketter et al., 2016).

First and regarding data, information stemming from data has been recognized as a central component for creating meaningful DSI initiatives (Arts et al., 2015). Therein, digital technologies such as the Internet of Things (IoT) enable information availability by systematically increasing data collection capabilities and transparency in productive environments (Yousaf et al., 2021). Associated DSI actions systematically identify, collect, and analyze data to detect DSI opportunities. Knowledge in this cluster presents the processes and actions performed to exploit the value of data. For example, Kelly and Noonan (2017) contribute to research by conceptualizing the difference between systematic and edifying datafication practices. Additionally, Sanders et al. (2021) show the potential of analyzing social media data to understand the public discourse surrounding a technology-centered topic (i.e., precision agriculture) in order to better understand user and customer preferences, doubts, and attitudes.

Second and regarding digital infrastructure, digital technologies as platforms and open-source software (e.g., P. Bhatt et al., 2016; Ketter et al., 2016) have proven to be a suitable tool for increasing DSI performance by fostering inclusion and (civic) participation of broader stakeholder groups (Yousaf et al., 2021). Digital innovation competitions (cf. Subchapter 3.1), open-source environments, platforms, or a mash-up of different collaboration applications allow broad stakeholder groups to participate in DSI actions (Maaravi & Heller, 2021; Richardson-Ngwenya et al., 2019). The increasing communication between firms, customers, universities, or public institutions on digital platforms leads to the formation of knowledge networks (Csedő et al., 2021). Digital platforms increase crowd management capabilities, accessibility to participation, automated results aggregation in crowdsourcing and potential for time-asynchronous work (Majchrzak & Shepherd, 2021). To leverage the positive effects of platforms, the importance of equal engagement of consumers and producers or a strong focus on the core platform interactions received attention in research (Kohler & Chesbrough, 2019).

In this realm, DSI is investigated, for example, in the context of institutional health service provision or the inclusion of marginalized groups in a community's transport planning (people) (P. Bhatt et al., 2016; Kelly & Noonan, 2017; Mehmood & Imran, 2021), or fostering nature conversation initiatives (planet) (Arts et al., 2015).

Research Cluster 2 – Digital Technologies as a Means and Outcome: Cluster 2 comprises research that focuses on DSI outcomes that create social value leveraged by digital technologies as a means. So far, research activities in this cluster are limited, as apparent in Figure 25.

Overall, two central topics have emerged: (1) specific digital technologies addressing societal challenges (e.g., Ahuja & Chan, 2020; Ciruela-Lorenzo et al., 2020) and (2), the general role of digital technologies for creating social innovation (e.g., Bonina, Koskinen, et al., 2021).

Regarding the usage of specific digital technologies in addressing societal challenges, scholars have investigated how the usage of digital technologies can help to tackle diseases. Thereby, farmers can be integrated in collecting large scale data through citizen-science, with the knowledge being used to get reliable and real-time information for disease prevention. Additionally, digital platforms can be used to share expertise on the disease and easily connect stakeholders (McCampbell et al., 2018). As another example, scholars have illustrated how a digital diagnosis tool can help agri-cooperatives in managing digital innovation. Thus, the tool can be used to analyze the digitalization process stage that the organization has reached as well as inform politics of the digitalization level of agri-cooperatives to have better designed political instruments of promoting a more sustainable environment (Ciruela-Lorenzo et al., 2020).

As for the second central topic, scholars designed a framework proposing varying IT investment types and an IT investment plan for organizations based on different stages of sustainability (Abraham & Dao, 2019; Abraham & Mohan, 2015). Further scholars show how digital platforms in general can be used to advance sustainable development as well as illustrate future research avenues and the downsides of digital platforms for development (Bonina, Koskinen, et al., 2021).

This cluster investigates DSI through all three sustainability perspectives, i.e., using digital platforms to address a disease that dangers stable food supply and the livelihood of the African banana farmers in terms of people and profit (McCampbell et al., 2018), or smart agriculture in terms of people, profit, and planet (Ciruela-Lorenzo et al., 2020).

Research Cluster 3 – Digital Technologies as a Means and Environment: Research activities in cluster 3 center on identifying contextual factors that either promote or hinder the success of DSI. The (1) internal and (2) external dynamics of DSI environments when innovating with big data, platforms, or other digital technologies are in focus.

First, and regarding the internal organizational environment, various factors were found to either promote or hinder the success of DSI. Management commitment and well-structured human resources practices, an open, participative, and green corporate culture and ethics, as well as a willingness to change and adopt new technologies, are among the relevant factors that positively impact the success of DSI (Arts et al., 2016; El-Kassar & Singh, 2019; Hsu et al.,

2019; Yang et al., 2016, 2017). Further, certain organizational roles are crucial for DSI success: project leaders and innovation intermediaries (Dong & Götz, 2021; Munthali et al., 2018).

Second, the external environment can strongly influence the success of DSI. External partners in the DSI ecosystem, such as pro-social stakeholder views (El-Kassar & Singh, 2019) or demographic and socio-economic characteristics such as a high level of democracy positively impact DSI. Simultaneously, a low gross domestic product and low social expenditure negatively influence the success of DSI in international DSI projects (Huh & Kim, 2019). From a technology-perspective, open-source code and crowdsourcing communities are promising approaches to increase knowledge integration with external stakeholders to positively affect DSI projects (Gogan et al., 2020). In such communities, different user roles (e.g., collaborator, contributor, passive users) emerge, where users can support with data collection, idea generation or idea evaluation (Fuger et al., 2017; Wehn & Evers, 2015). In addition, in the context of frugal innovation (i.e., innovation focusing on minimizing price, rather than maximizing functionality), actively leveraging ecosystems fosters the effective use of digital technologies for producing frugal innovations (Ahuja & Chan, 2014, 2016).

The sustainability of DSI in this cluster is understood in the environmental sense (i.e., planet), for instance, by investigating projects from environmental regulators (Arts et al., 2016) or green innovation initiatives in general (Yang et al., 2017). In terms of social sustainability, studies include, for example, an assessment of the role of agility in IT firms creating social value (Gogan et al., 2020).

Research Cluster 4 - Digital Technologies as an End and Actions: Research activities in cluster 4 center on DSI actions resulting in DT-based outcomes. This cluster is mainly (1) reporting on existing DSI cases and (2) synthesizing the learnings.

The majority of research in this cluster reports on case study findings into initiating, developing, implementing, and exploiting DSI initiatives in different contexts resulting in digital technology-based outcomes (e.g., Gerritsen et al., 2020; Hosseini et al., 2018) as well as overall findings and guidance across the different steps of DSI actions (e.g., Maffey et al., 2015; Regan & Wang, 2014). Different contexts are, for instance, the public sector, established organizations, specific industries, or society as a whole. To name examples: When initiating a DSI, Hosseini et al. (2018) illustrate that end-users should be included through open innovation approaches. Moreover, Gerritsen et al. (2020) investigate how different ways of initiation can lead to different ways of upscaling. As such when a techno-experiment is initiated by research

institutes, corporate actors and governmental actors these experiments develop in a self-referential way, whereas they tend to evolve as scattered spin-offs when being initiated by engaged individuals (Gerritsen et al., 2020). Further, when developing DSI under time and resource constraints it is important to rapidly iterate the solution with end-users, use available networks to repurpose existing resources, and integrate communities for co-creation (Vesci et al., 2021). Mashups can be used when there is a need to rapidly develop innovative solutions. As such existing products are combined into a new product to address short-term needs, as it was the case with the transaction of physical to digital education at the beginning of COVID-19 (Maaravi & Heller, 2021). For implementing a DSI, end-users should be integrated through co-creation and direct participation (Witteveen et al., 2017). Lastly, when exploiting a DSI, Furstenau et al. (2016) investigated a case of integrated care in Germany and found that once the care provider repositioned itself as high-quality care provider and making its competencies complementary to its organizational identity, they were able to scale themselves nationally and internationally. Further, Foster and Heeks (2013) describe the case of M-Pesa differentiating five phases of scaling, i.e., pilot, incremental rollout, aggressive growth, standardization, and functional expansion.

Regarding sustainability, this cluster mainly addresses people and planet. For one, people is examined in terms of for example quality education (Maaravi & Heller, 2021), ethical data practices (Aitken et al., 2021), and gender equality (Harvey & Fisher, 2013; F. Schmitt et al., 2020). For the other, planet is examined through, for example, nature conservation (Arts et al., 2015) or smart towns (Hosseini et al., 2018).

Research Cluster 5 – Digital Technologies as an End and Outcome: Research activities in cluster 5 center on (1) numerous individual successful DSI initiatives, (2) use cases for certain technology groups or industries/sectors, and (3), digital technology-enabled social business models. This cluster incorporates DSI knowledge that focuses solely on digital or physical-digital hybrid innovation as outcomes of DSI. Rather than considering the path it took to develop the respective DSI outcome, this cluster considers the nature or usage of outcomes once readily developed.

First, one central theme often presented in the form of a case study refers to specific digital tools or platforms that create a positive social impact. Therewithin, either the DSI outcome itself or effect mechanisms such as increased information availability, higher connectedness, or smarter and automated decision support are in focus (e.g., Abejirinde et al., 2018; Ahuja &

Chan, 2020; de Georgio Ferrari Trecate et al., 2020). Examples for such DSI include a digital platform for money lending in the developing world and a digital education platform providing knowledge on contraceptive care (Lassar et al., 2021; Ravishankar, 2021).

Second, use cases for technology types in specific contexts or general DSI application areas in specific industries and sectors have been identified (e.g., Bonina, Koskinen, et al., 2021; Hanelt et al., 2017; Tarafdar et al., 2013). In terms of technology types, research has demonstrated the diverse opportunities of IoT both in smart cities for pollution control or waste management (Cvar et al., 2020) as well as in healthcare for condition monitoring and respite care (Ghazal et al., 2021). Independent of the technology, the studies in our sample have shed light on potential use cases of DSI in smart cities, the educational sector, or public health systems (Agasisti et al., 2020; Kapoor et al., 2015; Rocha & Almeida, 2024).

Third, on a more abstract level, DSI can lead to IT-enabled business models (e.g., circular economy business models) (Cioffi et al., 2020; J. Han et al., 2020; Shomali & Pinkse, 2016) and can be classified through a taxonomy of DSI outcomes (Buck et al., 2020). To name just one example, digital energy service business models can positively affect the three sustainability dimensions (Hiteva & Foxon, 2021).

In terms of sustainability, this cluster covers a wide range of topics on planet (e.g., clean electricity or conservation management), people (e.g., substance abuse, recovery, maternal health), or profit (e.g., economic development at the bottom of the pyramid) (e.g., Abejirinde et al., 2018).

Research Cluster 6 – Digital Technologies as an End and Environment: Research activities in cluster 6 center on the impact of DSI environments when innovating for digital technology-based outcomes. In this realm, the focus is on two central themes: (1) internal organizational environment, for example, capabilities, team structure, culture or knowledge management, (2) external environment, for example, innovation spaces, regulations, cultural traditions or competition.

First and regarding the internal environment, the current focus is on non-human capabilities, for example, supporting IS (Hanelt et al., 2017), digital orientation capabilities of companies (Nasiri et al., 2022) as well as human capabilities, for example, capabilities of project leaders (Dong & Götz, 2021), coordinators (Arts et al., 2020) or personnel in general (Rodrigo & Palacios, 2021; Wunderlich et al., 2013). In this context, supporting IS can address sustainability on a larger scale and contribute to business success (Hanelt et al., 2017). Further,

companies with a high degree of digital orientation in their operation innovate more towards sustainable development than those with a lower level of digital orientation (Nasiri et al., 2022). Moreover, a professional's network, experience, and dedication are pivotal for DSI success (Dong & Götz, 2021). A high degree of anxiety and lack of life satisfaction, in contrast, leads to a lack of commitment from professionals in DSI organizations' development (Rodrigo & Palacios, 2021).

Second and regarding the external environment, the focus is on collaborations (Galán-Díaz et al., 2015; Koch et al., 2018), regulations, or the role of the public, such as social movements (Carberry et al., 2019), governments (Arts et al., 2016; Bloom et al., 2017; Butler & Hackney, 2015), or public value co-creation (Chatfield et al., 2019) influencing digital technology-based DSI. Social movements are more successful when applying field-level pressure. Thus, organizations comply with legal necessities, for example, the need for sustainability reporting. Organizations then innovate to develop digital technologies that can be leveraged to comply with these legal necessities (Carberry et al., 2019). Further, collaborations, for example, between organizations and academics can have positive and negative impacts. Hence, academics can support organizations in creating new ways of engaging with audiences. In contrast, negative impacts are reflected in the time and resources required to adopt new technologies or learn new skills (Galán-Díaz et al., 2015). Studies examine how regulation can influence companies' aims at innovating towards sustainable development. For example, introducing blockchain to the energy industry for issuing payments via cryptocurrency is seen as an incremental innovation which does not need regulatory adjustments as it is up to the energy retailer to accept the means of payment. In contrast disruptive innovation such as introducing blockchain to the energy sector that for instance reduces the boundaries of the natural monopoly, or complementing or substituting existing platforms are likely to need regulatory adjustments (Amenta et al., 2021).

This cluster's primary sustainability focus is on planet (e.g., nature conservation (Arts et al., 2020), electricity industry (Amenta et al., 2021)) and people (e.g., health system transition (Bloom et al., 2017), telemedicine (Alaboudi et al., 2016)). Profit is mostly regarded as a by-product when considering sustainability as a whole (e.g., Hjalmarsson & Lind, 2011; Nasiri et al., 2022).

6.4 Research Agenda for Digital Social Innovation

Based on the 135 studies, their classification into the six research clusters, and the in-depth analysis of their contributions, we identified research pathways that translate into a DSI research agenda. These research pathways are representative for a variety of research questions and aim at illustrating critical areas of research within DSI. We evaluated which gaps currently exist in research in each cluster. Further, we conducted 10 expert interviews with fellow IS scholars to discuss, extend, and refine the research agenda and the individual pathways' relevance based on the interviewees' feedback. In the following, we detail the resulting research pathways. Table 20 summarizes the 12 research pathways and their respective goals.

Cluster	Research Pathway	Goal
Cluster 1	RP1: What are the affordances of different digital technologies for DSI actions?	Supporting informed decision making regarding the selection and application of digital technologies during DSI actions.
	RP2: Which design principles best facilitate DSI actions in digital platform ecosystems?	Assessment of design principles for DSI ecosystems and development of recommendations for different DSI scenarios.
Cluster 2	RP3: How does the application of digital technologies within DSI actions change DSI outcomes?	Understanding how DSI outcomes change when integrating digital technologies in innovation processes and whether it positively affects sustainability goals in the DSI outcomes.
	RP4: How can digital technologies be used to measure the impact of DSI initiatives?	Gain transparency on social impact and on how to measure DSI success.
Cluster 3	RP5: Which stakeholder groups participate in DSI ecosystems and what are their motives?	Identification of the different groups participating in DSI ecosystems, their motives, and suitable incentive strategies for each group.
	RP6: How can digital technologies improve stakeholder involvement in DSI?	Analysis of the potential of different types of digital technologies for increasing stakeholder involvement in DSI initiatives across different stakeholder groups.
Cluster 4	RP7: How can DSI initiatives be designed to avoid potential downsides of digital technologies?	Assessment on how to best design a DSI initiative to harness its positive impact and subsequently avoid negative consequences.
	RP8: How can DSI actions ensure the DSI's technical interoperability with existing digital technology landscapes and workflows?	Assessment on how it can be assured within DSI actions that the DSI outcome is compatible with the existing digital technology landscape and the existing workflows.
Cluster 5	RP9: How can DSI initiatives address the dependencies and	Identification of relevant positive and negative dependencies between different sustainability dimensions and assessment of the role of digital

Cluster	Research Pathway	Goal
	conflicts between sustainability dimensions?	technologies in causing, increasing, or reducing these dependencies.
	RP10: How do digital technologies enable the scaling of DSI initiatives?	Examination of the potential of digital technologies and associated characteristics for increasing the scaling success of DSI initiatives.
Cluster 6	RP11: How to leverage interdisciplinarity among stakeholders in DSI?	Establishment of specific actionable requirements regarding interdisciplinarity (e.g., disciplines involved, communication formats) or understanding the role of interdisciplinarity within DSI.
	RP12: How can DSI succeed in resource-limited environments?	Investigation on how to adapt to constraints within a DSI ecosystem.

Table 20: Research Pathways for Digital Social Innovation

Cluster 1: Research has provided valuable insights into the role of digital technologies for increasing data access during innovation actions and the general role of data for innovating sustainably (e.g., Arts et al., 2015; Kelly & Noonan, 2017; Yousaf et al., 2021). For example, digital technologies can identify and assimilate knowledge to initiate innovation for societal challenges (Majchrzak & Shepherd, 2021). Further, IoT technology, in particular, has been researched as a tool for collecting data from production processes and other operations. In turn, it can be used to identify innovation opportunities in an organization's processes, services, and products (Da Xu et al., 2014). However, IoT is not the only promising digital technology for driving DSI, but other data-based digital technologies, such as artificial intelligence, machine learning, or virtual reality, already demonstrate a substantial potential for enabling organizations to drive sustainable solutions in traditional corporate innovation (Eom et al., 2024; Kakatkar et al., 2020). For example, artificial intelligence was shown to be more effective for routine-tasks than for highly creative activities such as ideation (Kakatkar et al., 2020). In the context of DSI, there is no assessment of the opportunities of different types of digital technologies for fostering DSI actions throughout the four DSI action steps initiation, development, implementation, and exploitation. IS research has previously applied the theoretical lens of affordances as "the possibilities for goal-oriented action afforded to specified user groups by technical objects" (Markus & Silver, 2008, p. 622). Affordance theory has the potential to assess the role of different digital technologies for changing and improving the four DSI action steps (C. Anderson & Robey, 2017). Additional approaches could consider different

technological archetypes or the varying technology purposes in order to better assess the suitability of different digital technologies within innovation actions (Baier et al., 2023). Such knowledge would be crucial for making informed decisions regarding the selection and application of digital technologies during DSI actions and it could drive the theoretical understanding of digital technologies affordances in DSI. Thus, the first research pathway central to the development of DSI reads:

RP1: What are the affordances of different digital technologies for DSI actions?

Cluster 1 also highlights the potential of digital platforms as technological infrastructure to increase participation and knowledge exchange in innovation endeavors (Ketter et al., 2016; Majchrzak & Shepherd, 2021; Richardson-Ngwenya et al., 2019). In the IS community, digital platforms as software artefacts are often not the central focus, but rather the platform-based ecosystem they are embedded in. Ecosystems are viewed as "interdependent network[s] of self-interested actors jointly creating value" (Bogers et al., 2019, p. 2), where actors in the case of DSI include firms, NGOs, the public, or policy makers. Digital platform ecosystem research focuses, for example, on the management of these actors, work practices within the ecosystem, selected technologies and the overall goal of innovating and competing (Costabile et al., 2022). Platform ecosystems enhance the efficiency and inclusiveness of DSI actions. For instance, they enable virtually connecting people to co-create solutions for societal challenges faster and at a larger scale (Bria, 2015; Majchrzak & Shepherd, 2021). The concept of crowdsourcing on innovation platform ecosystems is not new within DSI but has long been present in purely commercial contexts (Adamczyk et al., 2012; Gimpel et al., 2023). IT-enabled idea crowdsourcing and online innovation contests are two examples of concepts that leverage digital platforms to drive innovation (Adamczyk et al., 2012). The success of platform ecosystems is highly dependent on the right interaction with users and their motivation to participate appropriately. Hence, designing the ecosystem (e.g., governance, user interface, data protection mechanisms) in a way that best incentivizes people to contribute to DSI is crucial (Gimpel et al., 2023). Design science research has conceptualized this type of knowledge as design principles (Gregor & Hevner, 2013; Gregor et al., 2020; Yassaee et al., 2019) – i.e., the "design decisions and design knowledge that are intended to be manifested or encapsulated in an artifact, method, process or system" (Gregor, 2002, p. 17). Thus, we ask:

RP2: Which design principles best facilitate DSI actions in digital platform ecosystems?

Cluster 2: Research investigates the social value creation mechanisms and DSI outcomes when innovating with digital technologies during the DSI actions (i.e., digital technologies as a means). When developing innovation for societal challenges, digital technologies enhance the efficiency and inclusiveness of the development process. This is mirrored in the respective logics of business process management (i.e., process logic, infrastructure logic, agential logic) (Baiyere et al., 2020). Logics in general can be defined as "[…] the dominant way of thinking, which is reflected in terms of the assumptions, practices and values underlying the conception and associated actions in a specific context." (Baiyere et al., 2020, p. 239). Within the infrastructure logic of business process management, the dominant view is that the (digital) infrastructure should be in sync with the business process objectives. Thus, the application of digital technologies within DSI actions should be used to avoid inefficiencies and to facilitate connected departments, business units, and stakeholders (Baiyere et al., 2020). For instance, platforms can be used to virtually connect people (Fichman, 2004) to co-create solutions for societal challenges faster and at a larger scale (Bria, 2015). Despite the opportunities of digital technologies for DSI actions, there is no comprehensive knowledge on how the application of digital technologies within innovation changes DSI outcomes and whether it positively affects sustainability goals in the DSI outcomes. We, therefore, propose the following research pathway:

RP 3: How does the application of digital technologies within DSI actions change DSI outcomes?

Part of the outcome dimension in cluster 2 concerns the value creation and measurement of DSI solutions. A DSI initiative (usually) simultaneously creates social and economic value (Bonina, López-Berzosa, & Scarlata, 2021). While economic value is relatively easy to define and measure through economic key figures such as revenues or profit margins, social value is often highly subjective and implicit (Geobey et al., 2012; Popov et al., 2016). As a result, it is unclear how DSI success is defined and in terms of the created social value measured. That leads to the challenge that the success of a DSI initiative is hard to communicate to possible investors, customers, or beneficiaries. Also, DSI initiative prioritization is much harder to execute as the value of different initiatives cannot be compared easily. While this is an issue present also for traditional social innovation initiatives, to measure DSI success, digital technologies can play an important role. For example, energy monitors can be used to track how much energy is saved by using a more energy efficient solution (Rommetveit et al., 2024) or a smart garbage can be used to track how much waste was collected (Mohd Yusof et al., 2017). As transparency on

social impact is a key requirement for tackling sustainability challenges and thus measuring DSI success and its corresponding impact, we propose the following research pathway:

RP4: How can digital technologies be used to measure the impact of DSI initiatives?

Cluster 3: The impact of the internal and external organizational environment when innovating with digital technologies has not yet received a substantial amount of attention. However, given the often low motivation of users to participate in initiatives in digital innovation ecosystems, factors of the internal and external environment have emerged as central motivational drivers, making this research cluster central to DSI success (Renqiang & Wende, 2022). In the set of studies on digital technologies as a means, digital innovation ecosystems (e.g., on platforms) are central. However, not just the technological design is decisive for their expected impact (RP2), but also the people, or groups of people, cooperating in the ecosystem. Depending on the context, stakeholder groups contributing could include employees, corporate leadership, consultants, customers, technology users, policy makers, lobby groups, and others (Bonina, Koskinen, et al., 2021; Ketter et al., 2016). Each group and individual within such groups might have different intrinsic and extrinsic motivations for participating in DSI initiatives. For ecosystems to be effective, a deep understanding of the different stakeholder groups and differences in motivations is thus critical to select the right communication, interaction, and incentivization strategies. While this topic has been researched quite thoroughly in commercial contexts, participation motives in sustainability initiatives are less known. In this context, first studies have demonstrated that participation motives differ substantially in initiatives related to sustainable development (Say et al., 2021). Possible approaches to building knowledge in this area could build on the insights of studies such as Fuger et al. (2017), who use social network analytics to identify different user types based on their participation behavior in crowdsourcing. The first pathway in this cluster thus reads:

RP5: Which stakeholder groups participate in DSI ecosystems and what are their motives?

Research in cluster 3 widely agrees that diverse stakeholder groups' involvement is needed when tackling sustainability issues (Wamsler, 2017). For DSI, there has been special attention on digital platform ecosystems as a tool for fostering stakeholder involvement in various contexts, as discussed above. The particular value of digital platform ecosystems stems from their ability to bridge temporal and geographic distance between stakeholders. However, digital platforms are not the only possibility for stakeholders to contribute to DSI. For example, Arts

et al. (2020) and Wehn and Evers (2015) expand on the role of individuals as data collectors to improve the data availability needed for opportunity identification in DSI. In that context, self-tracking devices and wearables could also be valuable tools (Ghosh et al., 2022; Seshadri et al., 2020). While the research stream on digital platform ecosystems and the platform economy is quite mature, the potential of other digital technologies for improving stakeholder involvement is less known. Expanding on these research pathways could provide practitioners with more possibilities for external knowledge integration and help research to generalize knowledge on digital technology-enabled stakeholder integration beyond DSI contexts. Therefore, we propose:

RP6: How can digital technologies improve stakeholder involvement in DSI?

Cluster 4: Research within cluster 4 focuses on DSI actions, with the outcome being digital (i.e., digital technologies as an end), namely digital (or hybrid) products, services, processes, or business models. Although, digital technologies offer great many opportunities in addressing societal challenges, there are also downsides to consider. For example, the access to digital technologies may differ regarding generations (C. Kim & Feng, 2021) or regarding different geographical backgrounds (i.e., Global North and Global South) limiting the social impact of a DSI solution. Further, when focusing on specific digital technologies, AI for instance has many opportunities in addressing societal challenges (cf. AI for Social Good; e.g., Tomašev et al., 2020). However, it is also often being criticized regarding race, gender, or religion bias (Srinivasan & Chander, 2021). Furthermore, concepts especially regarding environmental sustainability often discuss the rebound effect. Generally, using technology is supposed to improve efficiency which then should lead to a decrease in resource use. However, oftentimes, an increase of efficiency through technology use does not lead to the same decrease in resource use or even leads to more resources being used due to behavioral changes and a subsequent increase in economic activities (Binswanger, 2001). This in return leads to negative environmental consequences. To avoid these issues, there needs to be a focus on how to best design a DSI initiative to harness its positive impact and subsequently avoid negative consequences. Against this backdrop, we ask:

RP7: How can DSI initiatives be designed to avoid potential downsides of digital technologies?

An organization implementing a DSI, often already has numerous other (digital) products, services, processes, or business models. Furthermore, DSI solutions are usually integrated into

existing workflows. Thus, DSI initiatives need to be designed in a way that makes them interoperable and easily integrated with other systems (Hodapp & Hanelt, 2022) as well as with existing workflows. Current DSI findings, however, neglect the challenge of selecting a digital technology that is suitable for the DSI initiative, while ensuring data availability and quality, data protection, and interoperability with existing digital technologies (Cichosz et al., 2020; Kayser et al., 2018). There is also little understanding of how the intended users can seamlessly work with digital technologies within DSI. For the latter, insights from the research field of human-computer interactions which focuses on the interaction between computers and their intended users as well as the subsequent design of user interfaces could further advance the DSI field (Brey & Søraker, 2009). Thus, an important research pathway is the assessment of how DSIs' compatibility with the existing digital technology landscape and the existing workflows can be ensured during development. We, therefore, propose the following research pathway:

RP8: How can DSI actions ensure the DSI's technical interoperability with existing digital technology landscapes and workflows?

Cluster 5: The many individual use cases of DSI initiatives that constitute this cluster, complemented by studies on technology groups, DSI in certain industries, or DSI business models, all show some positive sustainability impact. Positive advancements in one area of sustainability sometimes automatically trigger improvements in another area (e.g., better nutrition levels leading to improved health) (Biglari et al., 2022). However, there are also cases where negative conflicts between sustainability dimensions can arise. To just name two examples: (1) Higher resource efficiency caused by digitalization potentially leads to lower demand for the workforce and increases unemployment in certain sectors (Hilpert, 2021). (2) Implementing an app to save water and benefit the environment could discriminate against the elderly who do not have access to mobile phones. Research as well as projects such as the Agenda 2020 Compass - a collaboration between the *Stockholm Environment Institute*, the *MIT Center for Collective Intelligence*, and industry - have investigated these positive and negative synergies between all dimensions of sustainability (Biglari et al., 2022; Hallding & Blixt, 2020; Parthiban et al., 2020). To reach sustainable development in the long run, it is indispensable to understand how DSI causes, affects, or solves the synergies, conflicts, and relationships between sustainability dimensions early on. Otherwise, well-intentioned DSI initiatives could cause more damage than good. While this is most prominent in cluster 5, this topic is also relevant to cluster 2 and the corresponding innovation with digital technologies as a means for sustainability. Research should holistically address:

RP9: How can DSI initiatives address the dependencies and conflicts between sustainability dimensions?

The richness of contributions in this cluster is promising for the potential of digital technologies in DSI. However, looking at the achievement status of many of the SDGs, there is still much to be done (Sachs et al., 2023). Consequently, it is safe to say that the theoretical potential of DSI has not yet translated into positive sustainability effects to a full extent. To fully exploit the value of DSI initiatives, there is a need to understand how DSI initiatives can be successfully maintained and scaled after the initial prototypical implementation (Rodrigo & Palacios, 2021). The scaling of (digital) social innovations, however, has proven a tedious and often unsuccessful task (Voltan & Fuentes, 2016). Digital technologies have the potential to play a significant role in scaling DSI outcomes by making the DSI available across time and place more quickly than with purely analogue approaches. This is possible due to digital technology characteristics, such as their convergence, inexpensiveness, and availability across social classes, which enables reaching large parts of the population (Fichman et al., 2014; Foster & Heeks, 2013; Walsham, 2017; Yoo et al., 2012). Therefore, a further research pathway would be to investigate the specific possibilities of digital technologies and their characteristics for scaling a DSI initiative. Thus, we propose the following research pathway:

RP10: How do digital technologies enable the scaling of DSI initiatives?

Cluster 6: Research in this cluster focuses on the DSI environment, encompassing components such as knowledge management (Kohli & Melville, 2019) or innovation ecosystems and networks (Abrell et al., 2016; Hosseini et al., 2018; Jacobides et al., 2018; D. Schmitt & Muyoya, 2020). To master DSI endeavors, there is a need for knowledge both on (1) the underlying societal challenges as well as (2) the applied digital technologies. The societal challenges (e.g., climate change, poverty, poor education) that are addressed through DSI initiatives are often complex, ill-structured and highly uncertain (Weber & Khademian, 2008), making it difficult to develop solutions (Chalmers, 2013). On a technological side, developing DSI initiatives demands knowledge regarding digital technologies and their unique characteristics, possibilities, purposes, and risks (Baier et al., 2023; Kohli & Melville, 2019). Given the different knowledge streams required in DSI, there is a need for diverse stakeholder groups in terms of departments (e.g., IT department, innovation department) and in terms of societal backgrounds (i.e., diversity in age, gender, race) to interact, share their knowledge and bring in their different standpoints when developing DSI initiatives. This will increase the DSI

initiative's efficiency and helps to address the societal challenges in the best way possible (Charalabidis et al., 2014; Guinan et al., 2019). However, not only practice needs to consider an interdisciplinary perspective but also research. Hence, the IS discipline calls for adopting transdisciplinary perspectives in engaging with other disciplines to address today's societal challenges (Kar et al., 2019; Pappas et al., 2023; Walsham, 2012, 2017). IS research should see itself as "co-contributors with everyone else, since all people around the world have views about 'development' in their particular context" (Walsham, 2017, p. 37). While there is consensus about the general need for transdisciplinary perspectives, specific, actionable requirements regarding interdisciplinarity (e.g., disciplines involved, communication formats) or the role of interdisciplinarity within DSI are less established. Thus, we ask:

RP11: How to leverage interdisciplinarity among stakeholders in DSI?

When studying environments in which DSI starts to develop as the topic in cluster 6, there are different context factors to consider. For instance, DSI initiatives may differ when being developed in the Global North or Global South due to differences in organizations' resource bases, governmental regulations, or context factors such as varying climate conditions. Thus, when considering rural or remote regions, the starting point for developing DSI initiatives can be completely different than in highly industrialized regions. There are first studies that focus on developing DSI initiatives in rural regions. For instance, Tim et al. (2021) investigate in their practitioner's paper how grassroots communities in remote areas used e-commerce to "leapfrog" out of poverty. Leapfrogging means that a technology is adopted, while the previous version of that technology has not been adopted (Tim et al., 2021). As another example, studies investigate frugal innovation, i.e., innovation focusing on minimizing price, rather than maximizing functionality (Ahuja & Chan, 2014, 2016) and thus, minimizing resource use, such as water, energy, or fuel (Albert, 2019). Thus, there are first studies that investigate how to adapt to constraints within a DSI ecosystem. Advancing this research, we propose the following pathway:

RP12: How can DSI succeed in resource-limited environments?

6.5 Discussion

Reflecting upon the research pathways as well as the literature sample studied during our review, it becomes apparent that there are few central, reoccurring topics that drive DSI research in particular: (1) the role of DSI ecosystems, (2) the role of DSIs for potential conflicts

and synergies between sustainability dimensions, (3) the integration of DSI into different contexts and environments, (4) the role of data, and (5) the assessment of DSI success. These topics span a variety of the research pathways and research has already produced relevant insights for them. Figure 26 depicts how the five topics emerge from the general understanding of DSI. In the following paragraphs, each of the five topics and its implications for DSI are discussed.

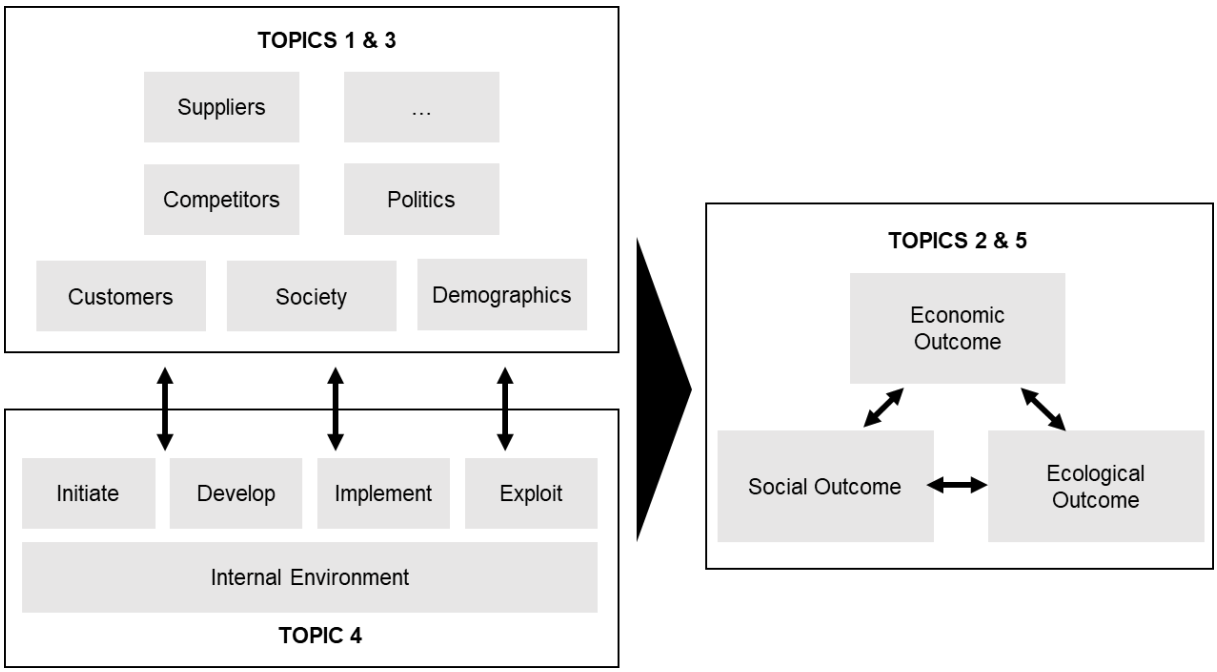


Figure 26: Central Topics Driving Digital Social Innovation Research

DSI ecosystems

The impact of digital technologies and ecosystems on DSI represents a significant area of research that requires deeper investigation. In general ecosystems are understood as multiple actors working together sharing a common destiny (Catala et al., 2023). Ecosystems hold many opportunities in the digital as well as the social domain. In the social domain ecosystems can help enhance social innovation through human capital, access to resources, connection between organizations, institutional strength, political will, and demand for goods and services (Biggeri et al., 2017). In the digital domain ecosystems can help organizations to stay competitive in light of digital disruption and create new business opportunities (Weill & Woerner, 2015).

Ecosystems are especially relevant for DSI, given their potential to overcome financial, temporal, and geographic barriers. Since DSI is a multifaceted phenomenon, different skills and different knowledge is needed to develop DSI initiatives. Ecosystems hold the opportunity to

connect stakeholders in order for them to share resources and capabilities (B. Bhatt et al., 2021). Furthermore, societal challenges are complex and oftentimes multiple stakeholders are needed for these challenges to be tackled. Ecosystems can help to create synergies between DSI initiatives from different organizations. This in turn helps to scale the DSI initiatives on a much faster level and unfold even greater social value instead of addressing these challenges on an individual level (B. Bhatt et al., 2021; Qureshi et al., 2021). IS researchers delve into these ecosystems to analyze how DSI initiatives are developed, shared, and utilized within ecosystems (Bogers et al., 2019; Costabile et al., 2022; Jacobides et al., 2018).

Within our analysis, different dimensions of ecosystem research appear as relevant, such as its technical design, the selection and incentivation of participants, or their integration into other digital technologies. In detail, the topic of ecosystems is especially mirrored in our research pathways on understanding the role of interdisciplinarity in DSI research, on how digital technologies can help to scale DSI initiatives, in understanding which stakeholder groups participate in DSI ecosystems and their corresponding motives as well as how digital technologies can improve stakeholder involvement within DSI.

DSIs for potential conflicts and synergies between sustainability dimensions

Sustainability is a massively interconnected, complex challenge (Hallding & Blixt, 2020), where solution quality (e.g., social impact) is often difficult or even impossible to measure. This is partly due to existing conflicts and synergies between and within the three pillars of sustainability (Reyers & Selig, 2020). Sometimes, achievements in one area of sustainability drive sustainability in another. For example, reduced poverty (SDG 1) almost always automatically leads to a reduction in hunger (SDG 2) (Shetty & Shetty, 2014). In other cases, achievements in one area inhibit or worsen the situation in another area. A prominent example is the positive correlation between a country's wealth (SDG 1) and the negative climate impact it produces (SDG 13) (Lægreid & Povitkina, 2018). However, to more effectively develop solutions to sustainability challenges, knowledge on interdependencies between sustainability dimensions and the impact of individual initiatives (or portfolios thereof) is indispensable.

For DSI, this topic is highly relevant for two reasons. First, innovators often start their innovation endeavor with focus on a specific sustainability challenge to be solved (e.g., reducing the carbon emissions of a production step). Throughout the innovation process, finding the best possible solution for that particular problem is the main goal. However, knowing the interdependencies between sustainability dimensions allows for finding a solution

not only optimal to the specific individual problem, but to sustainable development overall. Therein, reflecting on the direct and indirect impacts of DSI outcomes on the different areas of sustainability is crucial and adds to the topic of multi criteria decision analysis (Cinelli et al., 2014). Second, DSIs have an additional role in terms of synergies and conflict as they have the potential to reduce existing sustainability conflicts. For example, increased production efficiency and automatization (an increase in economic and environmental sustainability) can lead to unemployment (decrease in social sustainability) (Nakamura & Zeira, 2023). However, DSI solutions such as digital education and training tools can ease the transfer to new job positions and thus have a positive impact on the existing conflict (Witteveen et al., 2017).

The topic of interactions between sustainability areas is reflected within two of the research pathways. Both the assessment of potential downsides of DSI and the active management of synergies and conflicts lead to a more holistic perspective of sustainability within DSI.

DSI's integration into different contexts and environments

In the contemporary digital landscape, understanding the integration of DSI into diverse contexts and environments emerges as a critical area of inquiry. Broadly defined, contexts encompass the multifaceted socio-cultural, economic, within which DSI operates. These contexts are characterized by varying resources, policies, cultural norms, and organizational structures, shaping the landscape in which DSI initiatives unfold (Hilpert, 2021; Nasiri et al., 2022). In the digital age, the significance of exploring DSI's integration into different environments lies in its potential to inform the design of adaptable and context-aware IS solutions. Such solutions must account for the nuances of societal norms, cultural dynamics, and regulatory frameworks across diverse settings (Hong et al., 2014).

For DSI, this discourse holds particular relevance for several reasons. First, DSI includes an inherent emphasis on leveraging digital technologies to address societal challenges while fostering inclusivity in a diverse set of environments. The integration of DSI into various contexts becomes pivotal for achieving meaningful social impact (Foster & Heeks, 2013; Tarafdar et al., 2013). By understanding how DSI initiatives interact with and adapt to different environments, scholars and practitioners can elucidate strategies for optimizing their effectiveness and scalability. Second, it is evident that the adaptability of DSI initiatives is crucial to meet the diverse requirements and resources of different contexts. For instance, innovators of DSI initiatives in resource-constrained environments find innovative ways to achieve their goals by leveraging local resources and community networks (Foster & Heeks,

2013). Third, our findings have underscored that scaling DSI initiatives with digital technologies presents a complex challenge that requires thorough consideration of local conditions (Foster & Heeks, 2013; Voltan & Fuentes, 2016). Successful DSI strategies often rely on context-specific partnerships and collaboration models, enabling DSIs to adapt to the needs of their respective environments. Furthermore, we found that the composition and dynamics of actor groups in DSI ecosystems are heavily influenced by context-specific factors. For example, the cultural heterogeneity of a community can affect stakeholder collaboration, which in turn impacts the implementation and success of DSI initiatives. By considering these contextual factors, we can develop a deeper understanding of how DSI operates in different environments and how effectiveness-enhancing measures can be developed tailored to the specific needs and challenges on the ground.

The integration of DSI into diverse contexts intersects with the research pathways posed in this chapter. This refers to the participation of different stakeholder groups and their motives, the usage of digital technologies to scale DSI initiatives, and the success of DSI in resource-limited environments.

Role of data within DSI

The strategic utilization of data constitutes a crucial aspect for advancing DSI. Data, in its broadest sense, encompasses the availability, quality, and ethical use of information, serving as a cornerstone for steering DSI initiatives towards meaningful impact (Arts et al., 2016). Within the realm of DSI, data plays a multifaceted role, from informed decision-making processes to facilitating collaboration among diverse stakeholders (Aitken et al., 2021). However, navigating the ethical considerations and potential conflicts associated with data use in DSI initiatives presents a complex challenge (El-Kassar & Singh, 2019).

By leveraging data-driven insights, DSI initiatives can tailor their interventions to better meet the needs of communities, optimize resource allocation, and monitor progress towards desired outcomes. Moreover, data serves as a catalyst for innovation, enabling the development of novel solutions and the identification of emerging trends and opportunities. Within DSI, several aspects regarding data emerge from our analysis. Firstly, the quality and accessibility of data significantly influence the outcomes of DSI initiatives, highlighting the importance of robust data governance frameworks and digital accessible infrastructure (Kelly & Noonan, 2017). Secondly, ethical considerations surrounding data use emerge as important, to ensure secure, transparent, and participatory approaches to data collection, analysis, and sharing (Arts et al.,

2016). Furthermore, the interplay between data-driven decision-making and the social dimensions of DSI underscores the need for holistic approaches that prioritize both technological innovation and social equity. The transformative potential of data within DSI underscores the need for comprehensive frameworks that balance technological advancements with ethical and social considerations. By elucidating the role of data within DSI, further research should contribute to advancing knowledge on effective strategies for harnessing data-driven approaches to address complex societal challenges.

The integration of data within DSI intersects with the research pathways posed in this chapter on the affordances of different digital technologies for DSI actions, the measurement of DSI success, as well as on the design of DSI initiatives to avoid potential downsides of digital technologies.

The assessment of DSI success

Evaluating the success of DSI initiatives constitutes an important aspect. Success is very difficult to define, since it usually needs to be put into the different context that is examined. In research, one way of understanding success is often investigated through success factors, i.e., "those characteristics, conditions, or variables that when properly sustained, maintained, or managed can have a significant impact on the success of a firm competing in a particular industry" (Leidecker & Bruno, 1984, p. 24). Therefore, success factors indicate what is needed for an initiative to be successful. Moreover, measuring the success of initiatives varies between concepts. For instance, while the success of digital innovation initiatives and the associated created economic value is easy to measure due to economic key figures, the success of social innovation initiatives and the associated social value is hard to measure due to its subjectivity and implicitness (Geobey et al., 2012; Popov et al., 2016).

DSI initiatives create social and economic value. Thus, the success of DSI is not only multifaceted but also deeply intertwined with the socio-economic and environmental challenges it seeks to address. Therefore, traditional success metrics may not fully capture the nuanced and often intangible outcomes of DSI initiatives (Regan & Wang, 2014). Hence, developing comprehensive assessment frameworks that account for the interconnectedness of success dimensions is needed. This involves not only measuring the direct impact of DSI but also understanding the broader implications and potential conflicts that may arise (Cichosz et al., 2020).

The assessment of DSI success is mirrored within our research pathway that focuses on how digital technologies can be used to measure DSI's success. Therefore, by delving into the complexities of success measurement as well as utilizing the opportunities of digital technologies to more easily measure success, researchers can contribute to the refinement of evaluation methods tailored to the unique challenges and objectives of diverse DSI initiatives.

6.6 Contribution and Implications

Contribution

DSI is emerging as a significant area of research investigating how digital technologies can be used to create innovative solutions to societal challenges (Bonina, López-Berzosa, & Scarlata, 2021). Currently, DSI research is highly scattered across disciplines, terminologies, and outlets. By answering the call of Buck, Krombacher, et al. (2023, p. 13) for "further research in the DSI area so as to harness digital technologies' potentials to do good and to shape and develop the DSI field in the future", our aim was to reflect on existing contributions as well as critical research pathways for DSI by providing research clusters and a research agenda for DSI.

First, our research cluster's structure current DSI findings, drawing knowledge from different research streams, thus harmonizing a diverse range of research. Traditionally, DSI research has been dispersed across various academic disciplines, lacking a cohesive, as an integrated view that brings together all relevant facets. With the six research clusters and a summary of the insights generated within each of them, we provide a shared knowledge base of the themes researched in the domain of DSI. Therefore, our six research clusters provide an aggregated understanding of the different characteristics of DSI based on digital innovation, digital technologies, and social innovation helping to structure and categorize current DSI findings.

Second, building on the six distinct research clusters, we outline current research gaps and identify future research opportunities in the form of 12 research pathways. In line with Gregor's (2006) theory types, our research agenda can be understood as a first step towards a theory for analyzing (i.e., Type I) that describes the phenomenon of interest and commonalities found in discrete observation, laying the foundation for higher-order theories (i.e., theories for explaining, predicting, and design and action) (Gregor, 2006). Accordingly, our work contributes to the descriptive knowledge on DSI, which is needed when little is known about a phenomenon under considerations, i.e., in our case DSI (Gregor, 2006).

Summarizing, our work represents a significant synthesis and expansion of DSI research elucidating previously uncharted research pathways by offering a comprehensive overview of DSI research clusters and their associated research pathways. Thus, our research agenda serves as the cornerstone for future theoretical developments within the realm of DSI.

Theoretical Implications

While our research agenda addresses the IS discipline's call to better characterize and understand DSI (Buck, Krombacher, et al., 2023), it not only builds upon the foundational contributions of scholars like Bonina, López-Berzosa, and Scarlata (2021) and Qureshi et al. (2021), but also complements their work by offering a nuanced and holistic perspective on DSI. For instance, Qureshi et al. (2021) have opened up the opportunity space on research pathways that are of interest in the area of DSI. Based on our systematic literature review and our structure along the different research clusters, we narrow down this opportunity space by determining what has already been done. We have extracted the valuable knowledge from Qureshi et al.'s (2021) research framework and build upon it within the pathways of our research agenda. Following their contributions, our research agenda seeks to extend the discourse initiated by Walsham's (2012) imperative - 'are we making a better world with ICTs?'. We envision that the synergy between the DSI research framework and our proposed pathways will catalyze further interest and inquiry, fostering socially relevant and impactful research in the dynamic landscape of DSI.

For theory, the five topics presented in Subchapter 6.5 offer theoretical angles that are relevant for future research on DSI. In addition, the development of a DSI research agenda represents a shift toward a more structured and mature approach to this multidisciplinary field. With the development of the DSI field, the research community needs to complement individual, explorative case studies on DSI examples to directed, well-defined research endeavors in order to continue creating meaningful and impactful research output. The multidisciplinary nature of DSI implies that future DSI research will likely require theories and concepts from different fields (e.g., computer science, information theory, statistics, and other fields) to be co-created to build a comprehensive understanding of the evolving landscape. The research clusters can serve as a springboard for future sense-making and design-led research into DSI (Gregor & Hevner, 2013).

Looking at the distribution of studies across the six clusters portrayed in Figure 25, it also becomes apparent that not all clusters have received equal attention. Interestingly, research on

digital technologies as an end is much more present than digital technologies as a means. This implies that the shift of the IS community's perspective from viewing digital technologies as a mere infrastructure tool towards more recognition of its fundamental transformative effects as an enabler for new products, services, processes, and even business models has also been successfully integrated into DSI research (Vial, 2019; Wessel et al., 2021). While generally positive, this implication nevertheless calls for a balanced view regarding both roles of digital technologies in DSI (Nambisan et al., 2017) in order to not neglect the potential of digital technologies as a means in future research.

Practical Implications

Although the nature of research agendas implies a strong focus on implications for research, rather than practice, our work still provides practical value (Moeini et al., 2019). From a practical perspective, our work supports practitioners in understanding the relevance of DSI, providing a basis for observing, measuring, analyzing, and managing relevant aspects of DSI. First, the research agenda can serve as a roadmap for organizations to find inspiration for their DSI initiatives. Thereby, organizations can ensure that their efforts to leverage digital technologies is synergetic with IS research. Second, the research agenda can also facilitate collaboration and partnerships among organizations. Through collaboration in the research areas identified in the agenda, organizations can pool and allocate their resources effectively to achieve greater social and environmental impact. Third, the research agenda can inform organizations, governments. and regulatory environments on the persisting challenges of DSI. This might potentially enhance the success of DSI in the long-term.

Limitations & Further Research

In conclusion, our research agenda proposes 12 research pathways that can guide future research efforts in DSI. By exploring these areas, we can gain a deeper understanding of the potential of digital technologies to address some of the key societal challenges our society faces today. Like any research, our work has limitations, which, in turn, provide stimuli for future research.

First, our research agenda varies in its level of specificity to the phenomenon of DSI. While parts of the pathways (e.g., RP 9) are DSI-specific, others (e.g., RP5) are also transferrable to related phenomena within the IS research community (e.g., digital innovation in purely commercial settings). While we purposefully included both types of questions in order to comprehensively present the existing challenges in DSI, future research could leverage these

differences in specificity for a broader view on IS research agendas. For example, scholars could explore the possibility of conducting a meta-analysis on research agendas to unveil overarching themes in IS research.

Second, the scope of this Chapter was to synthesize existing research and provide relevant pathways for future research. Our research agenda, however, does not provide a prioritization of the pathways or a clear formulation of dependencies between them. This might lead to difficulties for practitioners in prioritizing where to allocate their efforts effectively. To address this limitation, future research could incorporate a prioritizing of these pathways. This prioritization could be based on various criteria, such as the urgency of the issues addressed, the potential impact of the research, or the level of interdependence between pathways. The introduction of a temporal dimension could also play a role in prioritization, recognizing that certain pathways may have greater relevance at different points in time.

Third, we performed interviews with 10 IS scholars to discuss and evaluate the research agenda. Future research can engage in evaluating the research agenda with not only more researchers, but also with practitioners or hybrid groups. Such discussion could help in translating the research agenda into actions for practitioners to continue driving DSI for sustainable development.

Looking forward, the analysis performed in this chapter pinpoints the main implications of existing DSI research for future research endeavors. Bringing together the existing knowledge creates an opportunity to drive the research field in a targeted manner. The findings on DSI also help identify the critical research aspects of digital innovation for sustainability.

7 Discussion and Conclusion

Collective action from individuals, governments, and organizations is needed to achieve sustainable development and address the many challenges associated with sustainability (e.g., climate change, pandemics, and social inequality) (Bexell & Jönsson, 2017; Head, 2008; Kolk & van Tulder, 2010). Organizations, in particular, face a dual role in this quest as they bear the responsibility of both applying sustainable practices in their own business operations as well as providing sustainable products and services to their customers (George et al., 2021; Seidel et al., 2013). Digital innovation is one promising pathway for organizations to create sustainability value internally and externally (Bähr & Fliaster, 2023; George et al., 2021; Joukhadar et al., 2023).

However, the full potential of digital innovation for sustainability has yet to be leveraged. The complex dynamics of social aspects (e.g., employee skills and mindset) and technical aspects (e.g., capabilities of new technologies) in digital innovation for sustainability are challenging to grasp (Avital & Te'eni, 2009; Hund et al., 2021; Msiska & Nielsen, 2018; Nambisan et al., 2017; Runde & Faulkner, 2019). Digital innovation actions are in a reciprocal relationship with the digital innovation environment, ultimately leading to digital innovation outcomes (Kohli & Melville, 2019). This dissertation aims to illustrate the dynamics of digital innovation for sustainability across multiple contexts to foster a better understanding of the processes within innovation actions, environments, and outcomes.

In terms of innovation actions, this dissertation's contribution is twofold. First, Subchapter 3.1 demonstrates how organizations can apply digital technologies and systems – in this case, online crowdsourcing and LLMs (X. Cheng et al., 2020; Thirunavukarasu et al., 2023) – to overcome the bottleneck of expert idea evaluations in external online innovation communities developing sustainable products, services, and processes. The subchapter highlights the potential of digital technologies not only as part of the outcome of the innovation process but also as a facilitator during digital innovation actions (Ciriello et al., 2018). Here, the general potential of LLMs and crowdsourcing as well as the best possible conditions for their application are in focus. Second, Subchapter 3.2. provides an understanding of *what* changes in the context of DT within and across different levels of analysis as well as a theorization of *how* change unfolds from an intra- and inter-level perspective. Developing digital innovation was found to be crucial to mastering DTs that achieve economic sustainability (Drechsler et al., 2020; Vial, 2019). The subchapter contributes to a better understanding of the role of digital

innovation in DTs by highlighting rapid prototyping, an entrepreneurial culture, ambidexterity, and the recombination of existing technologies as necessary digital innovation actions.

The innovation environment differentiates between the internal and external perspectives (Kohli & Melville, 2019). For the internal environment, this dissertation highlights the importance of navigating health risks associated with digital innovation (and the general usage of digital technologies at workplaces) in Subchapter 4.1. Technostress can occur when employees work with digital technologies (Ragu-Nathan et al., 2008; Tarafdar et al., 2007). Technostress decreases social sustainability (in the form of health and wellbeing) within the workforce and hinders the development of sustainable digital innovations (Chandra et al., 2019; Zhao et al., 2020). Therefore, 24 technostress prevention measures are provided, structured according to their characteristics and effectiveness for different sources of technostress. The subchapter contributes to the design of internal environments that enable digital innovation for sustainability. In the external innovation environment, customers are a critical component of digital innovation for sustainability. Subchapter 4.2 offers an analysis of the factors impacting pro-environmental behavior using the case of reusable systems in the to-go drinks and beverages sector. Building on the theory of planned behavior (Ajzen, 1985, 1991), the relevant factors impacting people's intention to use reusable systems are identified. The main contribution regards the potential of digital innovations to drive the adoption of sustainable solutions in the external environment. This includes the application of digital innovations to either improve information availability (information-based applications) or improve the context in which people decide for or against sustainable alternatives (process-based applications) (Seidel et al., 2013; Steg & Vlek, 2009).

Digital innovation outcomes comprise products, services, processes, and business models (Ciriello et al., 2018; Kohli & Melville, 2019). Chapter 5 develops a taxonomy to structure the field of digital innovations that drive urban agriculture. The taxonomy contributes to a better understanding of the scope of smart urban agriculture, differentiating characteristics, and different application possibilities (Nickerson et al., 2013). A set of organizational readiness factors further details requirements for leveraging the sustainability value of smart urban agriculture solutions. This chapter improves scientific understanding of how to structure the innovation outcome space for new, emerging technologies.

Chapter 6 abstracts individual contributions on innovation actions, environment, and outcomes and synthesizes existing knowledge on DSI on an aggregated level. Prior contributions are

clustered and analyzed using a multidimensional research framework. On that basis, 12 research pathways are the contribution of this chapter. Across the pathways, topics such as managing and understanding digital ecosystems, handling existing synergies between economic, social, and environmental sustainability, and measuring sustainability impacts reoccur. The resulting research avenues provide an outlook for future research on fundamental topics that the IS community may contribute to in order to drive the exploitation of sustainability value through digital innovation.

7.1 Implications for Theory

Across the different chapters, this dissertation contributes to understanding innovation actions, environments, and outcomes for digital innovation for sustainability. Subchapter 2.3 details five types of theory contributions in IS research and their applicability for this dissertation (Gregor, 2006). The research paradigm of this work is behavioral science. As such, the theoretical contributions of the individual chapters span theories for analyzing, explaining, and predicting – or combinations thereof (i.e., theories for explaining and predicting). The following paragraphs outline the theoretical implications according to the three theory purposes (i.e., analyzing, explaining, and predicting). This structures the theoretical implications of this dissertation across individual studies and constitutes the basis for the dissertation's meta-inferences in Subchapter 7.2.

Theory for Analyzing: Saying "What Is"

Table 21 maps the (sub)chapters and their theoretical contributions. The tick mark indicates that the respective chapter includes a theoretical contribution of the purpose of theory listed in the first column. The first purpose of theory presented in the following paragraphs is *analyzing*.

Purpose of Theory	**Innovation Actions**		**Innovation Environment**		**Innovation Outcomes**	**Synthesis**
	Subchapter 3.1	**Subchapter 3.2**	**Subchapter 4.1**	**Subchapter 4.2**	**Chapter 5**	**Chapter 6**
Analyzing		ü			ü	ü
Explaining	ü	ü	ü		ü	
Predicting	ü			ü		

Table 21: Theoretical Contributions by Chapter: Analyzing

Theories for analyzing describe a phenomenon of interest and focus on the description and analysis of *what currently is* (Gregor, 2006). In three of the chapters, this dissertation makes

contributions to the understanding of what is in terms of innovation actions, outcomes, and implications for digital innovation for sustainability.

Subchapter 3.2 centers around understanding *what* changes in the context of DT within and across levels of analysis and theorizing about *how* change unfolds from an intra- and inter-level perspective. Insights from studies on DT as a holistic process (i.e., the macro-level) are combined with research on its specific components (e.g., organizational agility or digital innovation) to create a synthesis of the extensive existing knowledge in the field (Agarwal et al., 2010; Oberländer & Leyer, 2022; Tallon et al., 2019). DT includes seven digital transformation themes (macro-level) consisting of 23 digital transformation patterns (meso-level), and 95 digital transformation initiatives (micro-level). The focus of Subchapter 3.2 is economic sustainability. However, DTs can also significantly drive social and environmental sustainability transformations in organizations (and vice versa) in a synergetic way (Graf-Drasch et al., 2023; Kneissel et al., 2023). The four identified change patterns around digital innovation are also crucial for theory-building in research focusing on social and environmental sustainability.

Such theoretical contributions belong to type one of Gregor's (2006) theory classification, and they are fundamental for building more extensive theories on the basis of critical digital innovation actions during DTs (Gregory & Henfridsson, 2021). For example, the four DT patterns identified within the theme of fostering digital innovation (e.g., fostering an entrepreneurial culture) can be used as constructs for empirical studies to detect relationships. Such studies could assess, for example, the relationship between the maturity of certain change constructs and outcome variables such as sustainability measures or DT performance. Knowing the impact of specific change patterns or initiatives could support practitioners in prioritizing the different DT activities effectively.

Chapter 5 provides theoretical contributions on the *what is* in terms of digital innovation for sustainability outcomes in the smart urban agriculture domain. Smart urban agriculture is one application context of digital innovation for sustainability that has positive effects on economic, social, and environmental sustainability (M. Carolan, 2020; Langemeyer et al., 2021). However, the topic is relatively new in research and practice, and there is little shared understanding of what it comprises.

One of the core contributions is a taxonomy of smart urban agriculture solutions. Taxonomies are a necessary step for conceptualizing new phenomena, such as new emerging technologies

or new application domains (Gregor, 2006; Kundisch et al., 2022; Nickerson et al., 2013). The taxonomy provides research a structuring tool for SUA in particular by helping to cluster groups of SUA solutions. As a result, research can assess relationships and properties for entire groups rather than individual use cases of SUA. The three building blocks (i.e., digital technology, data, and approach) capture the essence of the socio-technical solutions present in IS research (Lyytinen & Newman, 2008). The taxonomy helps researchers understand the different possibilities of applying digital innovations in urban agriculture and the different dimensions that distinguish the solutions.

With regard to research on digital innovation for sustainability, the chapter offers a blueprint for addressing and conceptualizing other emerging socio-technical innovation outcome fields in the future (e.g., generative AI) (Kundisch et al., 2022). This includes both the taxonomy development and evaluation procedure as well as the building blocks used to cluster the various taxonomy dimensions.

The last contribution regarding *what is* stems from Chapter 6 and the corresponding structured literature review on digital social innovation. Chapter 6 takes a meta-perspective across innovation actions, environments, and outcomes (M. Zhang & Gable, 2017) and answers the question of what is already known in DSI research in general and what is essential to know in the near future.

A total of 135 studies are synthesized and aggregated in a multi-dimensional research framework spanning the three dimensions of digital innovation, social innovation, and digital technologies. Again, the different dimensions capture the socio-technical nature of DSI (Lyytinen & Newman, 2008) and provide a helpful tool for structuring research contributions. The analysis increases transparency for existing insights, which enables other researchers to reduce redundancy (Webster & Watson, 2002). The analysis yields 12 research pathways that span five overarching topics: the role of DSI ecosystems, the role of DSIs for potential conflicts and synergies between sustainability dimensions, the integration of DSI into different contexts and environments, the role of data, and the assessment of DSI success.

DSI is shown to be one of the most central streams of digital innovation for sustainability, extensively covering topics around digital innovation actions, environments, outcomes, and all three pillars of sustainability (Bonina, López-Berzosa, & Scarlata, 2021; Buck, Krombacher, et al., 2023; Qureshi et al., 2021). The 12 research pathways contribute to future theory building by highlighting areas with high significance and low coverage.

Overall, this dissertation has theoretical implications to *what is* in digital innovation for sustainability research. The three central contributions are an understanding of digital innovation change actions in DTs (economic sustainability), a structuring tool for the outcome space in smart urban agriculture (economic, social, and environmental sustainability), and a synthesis of existing DSI research (economic, social, and environmental sustainability).

Theory for Explaining: Saying "How, Why, When, and Where"

Theories for explaining focus on understanding phenomena, corresponding constructs, and their relationships (Gregor, 2006). Contributions answer questions regarding *how, why, when,* and *where* things occur. In three of the chapters (Table 22), this dissertation makes contributions to theories for explaining digital innovation for sustainability.

Purpose of Theory	**Innovation Actions**		**Innovation Environment**		**Innovation Outcomes**	**Synthesis**
	Subchapter 3.1	**Subchapter 3.2**	**Subchapter 4.1**	**Subchapter 4.2**	**Chapter 5**	**Chapter 6**
Analyzing		ü			ü	ü
Explaining	ü	ü	ü		ü	
Predicting	ü			ü		

Table 22: Theoretical Contributions by Chapter: Explaining

Subchapter 3.1 analyzes the potential of crowdsourcing and LLMs for replacing expert juries in idea evaluation during innovation contests on complex problems such as climate change. It provides contributions regarding the potential of digital technologies as a means for facilitating and conducting evaluation tasks in digital innovation actions in sustainability contexts. This subchapter answers *why* evaluation performance is not consistently high and *when* and *where* (i.e., under which conditions) different decision-makers can best be leveraged.

The results imply that both crowds and LLMs yield evaluation results that generally make them suitable decision-makers. However, contest specialization and the evaluation procedure significantly impact performance (Blohm et al., 2016; Görzen & Kundisch, 2016; C. Riedl et al., 2010). For crowds, contest specialization is an inhibitor of evaluation performance, with higher specialization leading to worse performance. This is essential for crowdsourcing research and complements existing knowledge on using crowdsourcing during research as well as research on the phenomenon of crowdsourcing itself (e.g., Blohm et al., 2013; Chmielewski & Kucker, 2020; Gimpel, Graf-Drasch, et al., 2020).

With regard to digital innovation for sustainability theory, the subchapter shows that organizations can outsource part of the innovation actions to fully digital (LLMs) or digitally-

enabled (crowdsourcing) decision-makers to increase efficiency during the innovation actions. However, the level of specialization and the evaluation procedure need to be accounted for in the decision of when and where to apply the decision-makers. This is particularly relevant in this context as many sustainability challenges are highly specialized (Head, 2008; Karvonen & Brand, 2009; Lönngren & van Poeck, 2021). In fact, specialization and the evaluation procedure are part of the reason the evaluation performance is not consistently high.

In addition to knowledge on what changes in DT, Subchapter 3.2 contributes to explaining *how* change unfolds across levels of analysis.

The subchapter demonstrates that DT initiatives at the micro-level belong to either an episodic or continuous form of change. At the higher levels, change (and the respective change constructs) increasingly move towards a hybrid nature because of aggregation and balancing effects. This has substantial implications for theory as current opinions on change in DT strongly differ. Some view DT as continuous change (e.g., Chanias et al., 2019; Vial, 2019; Warner & Wäger, 2019), some consider it episodic change (e.g., Drechsler et al., 2020; Fuchs & Hess, 2018; Gregory et al., 2018; Piccoli et al., 2024), and others feel it is a mixture of both (e.g., Hanelt, Bohnsack, et al., 2021). The subchapter presents explanations for why opinions differ and how they can be integrated.

In relation to digital innovation for sustainability overall, a multi-level understanding of change offers guidance in managing digital innovation actions at different levels of analysis in order to best achieve sustainability value.

Subchapter 4.1 contributes to explaining and understanding technostress prevention at the workplace. It explores *how* to create innovation environments for digital innovation for sustainability that are healthy for employees and foster productive work. In addition, propositions regarding *when* and *where* to apply which technostress prevention measures are provided.

This dissertation derives 24 technostress prevention measures from literature and an extensive Delphi study. Each measure is characterized according to several characteristics, such as its role as a primary or secondary prevention measure, the entity of change (i.e., technology, organization, individual), target group, or effect and implementation duration. For theory, such a characterization enables an efficient grouping of measures for future empirical studies (Nickerson et al., 2013).

In addition, the results contribute propositions on the effectiveness of different technostress prevention measures for the set of technostress sources. These propositions indicate *when* and *where* the individual measures might be beneficial. The relationship between technostress prevention measures and technostress sources is complex. Some prevention measures address only one technostress source; others address multiple sources simultaneously. Similarly, some technostress sources can be mitigated with many measures, while others can only be addressed through a few specific measures. The resulting complexity underscores research's responsibility to develop knowledge on the effectiveness of different portfolios of prevention measures and the corresponding selection procedure.

Regarding digital innovation for sustainability research, the results contribute to understanding how to create (digital) work environments that are socially sustainable regarding health and wellbeing. The characterizations and propositions generate a better understanding of internal innovation environments and their requirements for effectively driving innovation actions.

Chapter 5 presents a multi-method approach with two fundamental contributions (Mingers, 2003). Next to the taxonomy for SUA, the chapter identifies 20 readiness factors for organizations to consider when planning to leverage SUA solutions. The readiness factors shed light on *how* to better achieve sustainability value in smart urban agriculture and *why* current initiatives might have failed regarding the expected outcomes.

The SUA readiness factors span the categories of resource readiness, cultural readiness, strategic readiness, partnership readiness, and regulatory readiness. For theory, the factors enable a better understanding of why existing initiatives might fail (i.e., because certain readiness factors are unmet). In addition, the readiness factors are antecedents to adoption theory (Jöhnk et al., 2021). Empirical studies on SUA adoption could assess the impact of each readiness factor on adoption intentions, actual adoption, and sustainability value realization (Jöhnk et al., 2021; Molla & Licker, 2005; Scur et al., 2023).

The results highlight the importance of assessing the requirements of leveraging a new digital innovation to reach the desired outcome. In addition, the results demonstrate that requirements are not purely technical (e.g., technical resource readiness) but also include social components such as cultural readiness. The 20 readiness factors are contextualized to SUA (Hong et al., 2014), but the underlying categories could serve as a basis for other contexts of digital innovations for sustainability (Giua et al., 2021; Knierim et al., 2018; Yigitcanlar et al., 2022).

Overall, this dissertation provides theoretical contributions to the *how, why, when, and where* of explaining digital innovation for sustainability. The four central values are an understanding of the potential of digital technologies as a means of facilitating idea evaluation during innovation actions (economic, social, and environmental sustainability), insights regarding how change unfolds in DTs (economic sustainability), knowledge regarding the design of healthy work environments for digital innovation (social sustainability), and a conceptualization of how to increase readiness for SUA initiatives (economic, social, and environmental sustainability).

Theory for Predicting: Saying "What Is and What Will Be"

Theories for predicting develop testable propositions for predicting an outcome based on a set of explanatory variables (Gregor, 2006). In theories that include predictions, questions regarding what is and *what will be* are answered. In two of the chapters (Table 23), this dissertation makes contributions in the form of theories for predicting aspects of digital innovation for sustainability.

Purpose of Theory	**Innovation Actions**		**Innovation Environment**		**Innovation Outcomes**	**Synthesis**
	Subchapter 3.1	**Subchapter 3.2**	**Subchapter 4.1**	**Subchapter 4.2**	**Chapter 5**	**Chapter 6**
Analyzing		ü			ü	ü
Explaining	ü	ü	ü		ü	
Predicting	ü			ü		

Table 23: Theoretical Contributions by Chapter: Predicting

In Subchapter 3.1, the main contribution is a better understanding of the potential of crowdsourcing and LLMs for evaluating ideas in innovation contests. As a secondary contribution, it also analyzes the effect of different evaluation variables on the final decision to advance or not advance an idea. It therefore examines *what will be* in terms of the final jury decision during innovation actions.

Through regression models, the subchapter demonstrates that for all three decision makers – i.e., expert juries, crowdsourcing, and LLM-based evaluations – the perception of a proposal's novelty, feasibility, impact, and presentation positively impacts the final decision regarding advancing a proposal. The regressions reveal two central implications for theory. First, the human evaluators (i.e., experts and crowds) are more easily predictable through their assessment of the four variables. In contrast, it is less clear how the LLM decides to advance or reject a proposal. This adds to current debates on explainable AI and issues with trusting black-box outcomes of AI (Bauer et al., 2023; Herm et al., 2023; B. Kim et al., 2023). Second, for

crowds, the impact of presentation increases with higher specialization. Accordingly, crowds mainly rely on the presentation format for high levels of specialization as they struggle to grasp novelty, feasibility, or impact. For research, this indicates the need to assess countermeasures enabling good crowd performance even under high levels of specialization.

Regarding digital innovation for sustainability research in general, the predictions reveal the limited predictability of AI outcomes despite their excellent performance. In addition, the crowd's susceptibility to visual cues is an essential revelation regarding humans' role in innovation actions in general.

Lastly, Subchapter 4.2 assesses the context of to-go reusable systems in the drinks and beverages industry. The contribution is twofold. First, it answers what is and *what will be* regarding people's decisions to use TGRS. Second, it analyzes *what is* in terms of digital innovations used to improve the adoption of TGRS.

Customers are a central component of the external innovation environment. If products and services are not aligned with customer needs, adoption rates will be low, and sustainability values cannot be realized (Greenwood et al., 2021). Subchapter 4.2 identifies environmental norms, subjective norms, attitude, context, and perceived behavioral control as relevant factors impacting people's intention to use TGRS. Building on the TPB (Ajzen, 1985, 1991), these factors are central leverage points for improving pro-environmental behavior in the context of TGRS. Consequently, it is insufficient to offer an impeccable solution from a technical perspective; rather, a solution must also consider the social perspective (e.g., social norms) to motivate customers to adopt TGRS. For theory, the model predicts what customers' intention will be to use TGRS depending on the underlying adoption factors.

In a second step, the subchapter analyzes what digital innovations are currently being applied to improve adoption rates. The 15 identified applications are mapped against the adoption factors and sorted into information- and process-based applications of digital innovation (Seidel et al., 2013; Steg & Vlek, 2009). For theory, the mapping provides a structure for assessing digital innovation's potential to increase the adoption of sustainable solutions. It also reveals that digital innovations' potential for improving the context and leveraging environmental norms is capitalized on substantially more than its potential for fostering social norms.

In relation to digital innovation for sustainability, the subchapter provides knowledge of the external innovation environment in the form of customers. The contextualized TPB illustrates how to adapt existing adoption theories to contexts of pro-environmental behavior. The

applications of digital innovations in real-life TGRS firms serve as a knowledge base for driving pro-environmental behavior.

Across Subchapter 3.1 and 4.2, this dissertation provides theoretical contributions to *what is* and *what will be* by predicting outcomes surrounding phenomena related to digital innovation for sustainability. The elements of theories for predicting support understanding and management of human behavior, first in terms of better predicting the potential of different decision-making groups throughout the innovation process (economic, social, and environmental sustainability), and second by predicting customer adoption of digital innovations for sustainability (environmental sustainability).

7.2 Meta-Inferences

The chapters of this dissertation center around the categories of digital innovation actions, outcomes, environments, and a meta-perspective on digital social innovation. However, the implications of each chapter are not solely bound to one category. Indeed, the different chapters also have implications for parts of the other categories.

To bring the implications of each chapter to a more abstract level, the following paragraphs highlight meta-inferences. Meta-inferences in this dissertation are insights that emerge when bringing together the knowledge generated across chapters. In other words, what can only be learned about digital innovation for sustainability when combining knowledge from different chapters? In this dissertation, meta-inferences are leveraged to abstract from the quantitative and qualitative insights within the individual categories (i.e., actions, environments, outcomes) and derive more general insights for digital innovation for sustainability. By jointly assessing the contributions within each of the three categories, inferences are derived for the other two categories. For example, the meta-inferences explicate the lessons from the contributions regarding innovation actions for innovation environments.

Meta-inferences based on knowledge generated on digital innovation actions

Chapter 3 focuses on knowledge of digital innovation actions. The innovation actions, however, strongly influence the innovation environment (Figure 27). This relationship is also highlighted in the two studies on digital innovation actions. In particular, two meta-inferences can be derived.

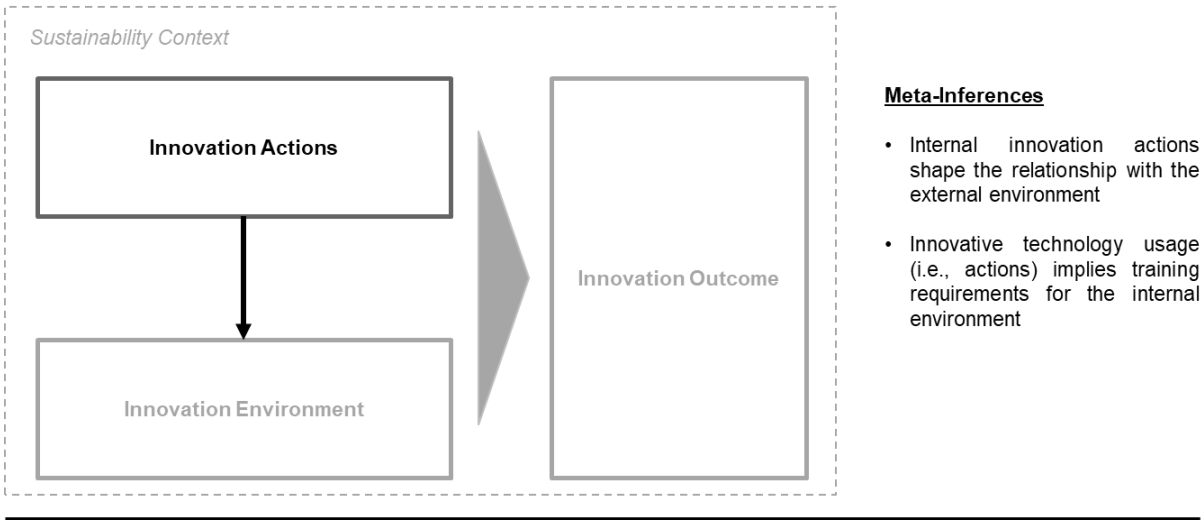


Figure 27: Meta-Inferences Derived from Digital Innovation Actions

1: Internal innovation actions shape the relationship with the external environment

Digital innovation for sustainability actions require a broad knowledge base and expertise. This applies both to the complex nature of sustainability challenges and the development of new digital technologies (Liang Li et al., 2018; Puvaneswaran & Alsdorf, 2021; Soluk & Kammerlander, 2021). When organizations start to conduct digital innovation actions, their activities impact their relationship with the external environment as they are dependent on integrating insights from customers, competitors, or suppliers (cf. Subchapter 3.2).

As in the case of idea evaluation in Subchapter 3.1, organizations increasingly reach out to their ecosystem to integrate knowledge and skills or outsource parts of the innovation process (X. Cheng et al., 2020; Chesbrough, 2006). This significantly impacts the external environment as the ecosystem is more involved with the innovating organization, can increase the organization's knowledge base through participation, and has higher stakes in driving innovation. This dissertation investigates the integration of the external environment in idea evaluation. Additional actions could include idea generation, open development processes, or beta tests with the ecosystem.

For organizations innovating digitally for sustainability, this inference calls for planning innovation activities that go beyond internal interests and resources. Rather, an integrated perspective on the external environment's potentials, requirements, and limits is necessary to drive innovation.

2: Innovative technology usage (i.e., actions) implies training requirements for the internal environment

Digital innovation actions impact not only the external environment but also the internal organizational environment. The choice of innovation actions has the potential to affect employee skills, work culture, and requirements for the overall workplace design (Dery et al., 2017; Müller et al., 2019). When organizations want to include rapid prototyping (as in Subchapter 3.2), this decision imposes requirements regarding the availability of technical infrastructure at the workplace and employee capabilities related to prototyping processes. Similarly, the decision to include crowdsourcing or LLM-based evaluations in the innovation actions (cf. Subchapter 3.1) demands training employees in implementing, managing, and using crowdsourcing or LLMs. Next to purely technical skills, choices in digital innovation actions must also be communicated and monitored in the internal environment to reach employee acceptance and trust in the novel forms of innovation.

Overall, the selection of innovation actions inherently forms a list of requirements for the internal environment and thus informs the design of the internal environment. This relates to both technical and social aspects such as employee training and skills, culture adaptations, and workplace design.

Meta-inferences based on knowledge generated on digital innovation environments

Chapter 4 focuses on knowledge of the digital innovation environment. However, the innovation environment is not an isolated system. It strongly impacts the innovation actions of an organization seeking to innovate digitally for sustainability (Figure 28).

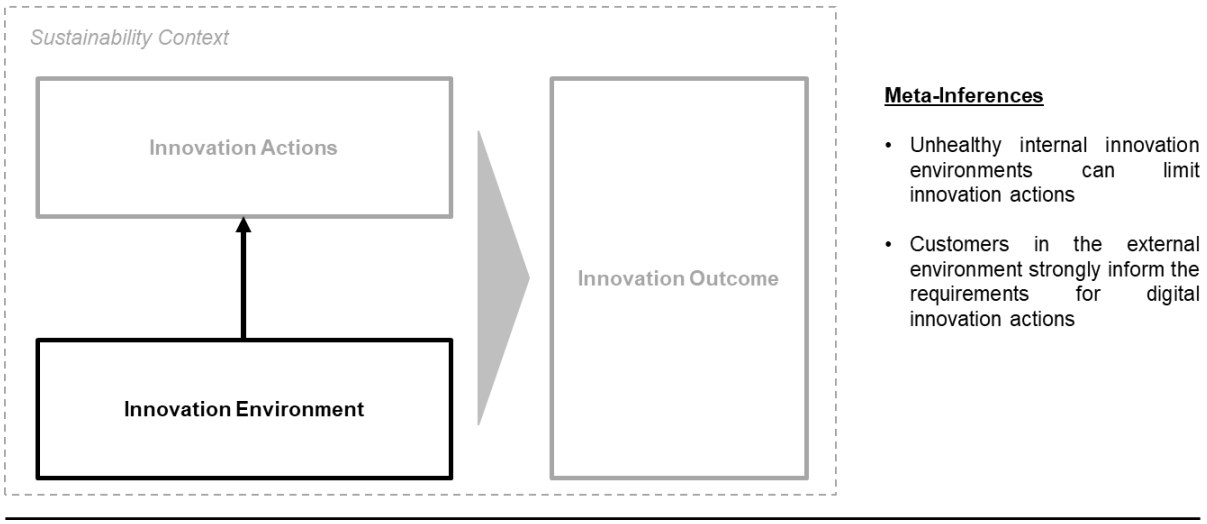


Figure 28: Meta-Inferences Derived from Digital Innovation Environments

3: Unhealthy internal innovation environments can limit innovation actions

In ideal socio-technical systems, the social component (e.g., employees in the internal environment) and the technical component (e.g., technology used and developed in innovation actions) are balanced and aligned with each other (L. H. Fischer & Baskerville, 2023; Lyytinen & Newman, 2008; Sarker et al., 2019). However, when internal organizational environments are not aligned with the needs of digital innovation actions, they can severely impair the potential of digital innovation for sustainability outcomes. As seen in the case of technostress (Subchapter 4.1), employees can be overwhelmed and face negative health consequences due to their work with digital technologies (Ragu-Nathan et al., 2008). If prevention measures (e.g., training, workplace design, etc.) are not in place, employees will no longer be able to support the planned innovation actions sufficiently as sick days will increase and productivity will decrease. What follows is that innovation actions cannot be chosen solely based on what is necessary for the desired outcome but must be selected in combination with what the internal environment can provide.

For example, if not trained and informed correctly, employees might resist working with AI due to a lack of trust and knowledge of the underlying functionality. As a result, including LLMs in innovation actions (cf. Subchapter 3.1) might no longer be possible. The overall internal organizational environment thus frames the opportunity space for digital innovation actions by the innovating organization.

4: Customers in the external environment strongly inform the requirements for digital innovation actions

The example of reusable to-go options in the beverages sector (Subchapter 4.2) demonstrates how sustainable products and services only realize their potential when their value proposition is aligned with customer needs. The demands and requirements of customers regarding digital innovations for sustainability thus strongly impact what should be done during digital innovation actions. If customers prefer certain features or technologies, these should be incorporated during the innovation actions. While this is not a new revelation (Kopalle et al., 2020; Shalini et al., 2021; Toubia & Florès, 2007), the dual role of digital innovations in this relationship between customers in the external environment and innovation actions is less prominent in research. On the one hand, digital innovations can be part of the digital innovation outcome. Here, customers have specific wishes regarding technology features and interfaces that should be included as aims during digital innovation. On the other hand, digital technologies can help to a) understand customer needs in the first place and b) drive adoption and usage behavior after the initial innovation actions. Data on the external environment is valuable for understanding customer needs during innovation actions (Kelly & Noonan, 2017). Simultaneously, as shown in Subchapter 4.2, digital innovations can support customers in adopting pro-environmental behavior by reducing existing barriers.

Meta-inferences based on knowledge generated on digital innovation outcomes

Lastly, this dissertation has developed a conceptual understanding of digital innovation outcomes in the context of smart urban agriculture. Beyond the aforementioned contributions for the outcome category, it also drives scientific understanding of digital innovation actions and environments (Figure 29).

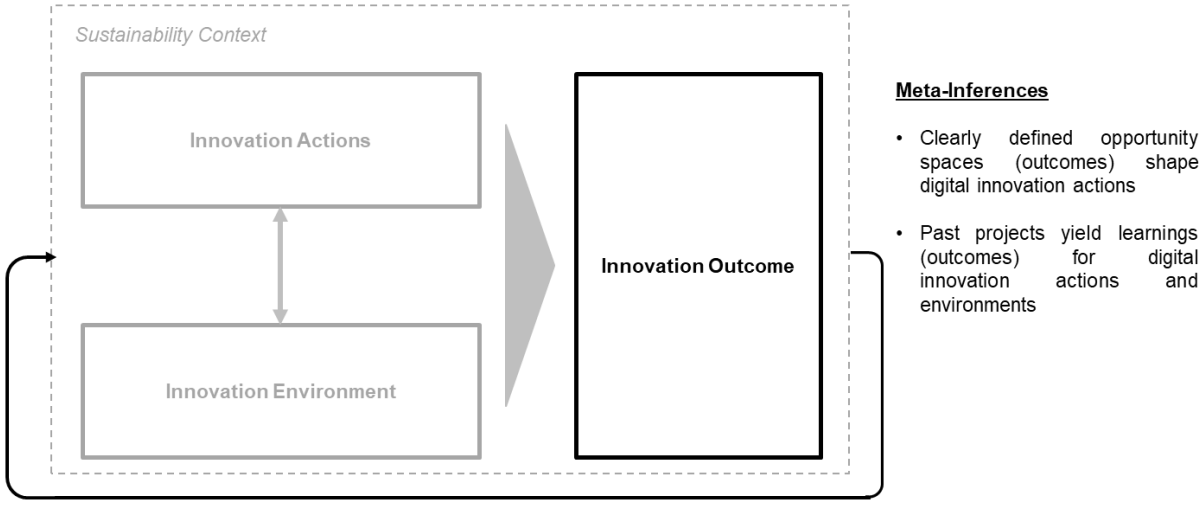


Figure 29: Meta-Inferences Derived from Digital Innovation Outcomes

5: Clearly defined opportunity spaces (outcomes) shape digital innovation actions

Chapter 5 presents a taxonomy for smart urban agriculture outcomes structured along the building blocks of *digital technologies*, *data*, and *approach*. Such a classification of an opportunity space for a specific technology or context can only arise with a certain maturity and when different outcomes have already become visible (Nickerson et al., 2013). Knowing the scope of a particular innovation outcome group has implications for digital innovation actions and environments.

The taxonomy guides and simplifies the ideation period for innovation actions because there is a clear spectrum of outcome options to choose from. In addition, the differences between the various outcomes become clearer through the characterization of dimensions in the taxonomy. Organizations ideating in a given context can assess the various characteristics and decide the individual fit for their innovation endeavor. For example, innovation contests (cf. Subchapter 3.1) could tailor the ideation to certain technologies or use cases. Hence, a sound understanding of the outcome space defines suitable innovation actions and offers a more precise target during the digital innovation actions. This is particularly relevant in sustainability contexts as the underlying challenges and respective solutions are often complex, with no simple solution existing (Head, 2008; Lönngren & van Poeck, 2021; Rittel & Webber, 1973b).

6: Past projects yield learnings (outcomes) for digital innovation actions and environments

When executing projects related to digital innovation for sustainability, organizations create various types of outcomes (Kohli & Melville, 2019). Sometimes, this process ends successfully, with an outcome that achieves the desired economic, social, and environmental impact. However, other times, digital innovation projects fail (Aladwani, 2002; Cichosz et al., 2020; Gurbaxani & Dunkle, 2019). Chapter 5 transforms lessons from successful and unsuccessful past innovation endeavors into organizational readiness factors (Jöhnk et al., 2021).

The resulting readiness factors inform the design of digital innovation actions and environments for future projects. For example, projects might fail because employees do not understand the importance of the respective innovation, fomenting resistance. As a response, future endeavors might incorporate change management more intensely within the internal environment – for example, when leveraging LLMs within the idea evaluation process (cf. Subchapter 3.1).

This dissertation highlights the strong interdependence between the three categories in socio-technical digital innovation for sustainability ecosystems. The expected outcomes arise only when innovation actions and environments are designed jointly and in alignment (Sarker et al., 2019). Focusing only on innovation actions or environments in isolation leads to imbalances that hinder the successful exploitation of sustainability value. This inference is further strengthened by the results of Chapter 6, which highlight an ecosystem perspective as one of the central research pathways for driving DSI.

7.3 Practical Implications

In addition to contributions to theory and meta-inferences regarding digital innovation actions, environments, and outcomes, this dissertation has implications for practitioners. The individual chapters provide detailed practical implications based on the results. Taken together, three overarching implications for practitioners emerge from the results.

Managing the various roles of digital innovations in attaining sustainability: The insights generated on digital innovation actions shed light on the different roles of digital innovations in a sustainability context. This dissertation highlights three potential ways for practitioners to leverage digital innovations to foster sustainable development. First, digital innovations can be the outcome of an innovation process. For example, this dissertation highlights the various digital innovation outcomes of smart urban agriculture. Here, practitioners are called upon to develop digital innovations that improve economic, social, and environmental sustainability. Examples include energy management systems, health apps, and digital education tools.

Second, practitioners can use digital innovations as facilitators during innovation actions targeted at sustainable solutions. In these cases, the outcome of the innovation process is not necessarily digital. Instead, digital innovations such as digital platforms or advanced data analytics solutions can be integrated to increase knowledge exchange and efficiency and to improve collaboration throughout ideation, development, or implementation.

Third, even after a digital innovation for sustainability is released, the application of additional digital innovations might be suitable. Scaling and keeping adoption levels high is difficult for innovators (Buck, Kempf, et al., 2023). Digital innovations can motivate people to engage in sustainable behavior and use their respective innovations. Digital nudging for sustainable choices or data collection to better understand customer behaviors and needs are two examples of using digital innovations to improve adoption levels after initial innovation actions.

This dissertation pinpoints the potential of digital innovations for sustainability beyond the mere development of a new app or digital tool. Practitioners should evaluate the potential of all three application possibilities to best achieve the three pillars of sustainability.

Aligning and enabling innovation environments: The internal organizational and external competitive environment significantly impact digital innovation actions. If neglected, the innovation environment can limit the potential of digital innovation for sustainability. One such example is the case of technostress discussed in Subchapter 4.1. For practitioners, this results in the responsibility to manage the innovation environment in two ways: aligning and enabling.

First, practitioners must align their internal environment and relationships with the external environment with the strategic goals of their digital innovation for sustainability actions. Internally, this includes the design of workplaces that match the innovation action requirements, properly training employees, building a digital work culture, or establishing recruiting programs. Regarding the external environment, practitioners must create a knowledge ecosystem that enables exchange and collaboration. This includes ties to suppliers, customers, or even competitors.

Second, practitioners should equip their environment to best contribute to digital innovations for sustainability. To this end, the environment should be provided with the opportunity to explore original creative ideas beyond the prior, existing ideas of the core innovation team. Creating space for the innovation environment to develop creativity could lead to substantial contributions beyond what was initially planned. Such enabling could include dedicated time and space for employees to contribute their ideas or the involvement of the external environment in innovation contests.

Overall, practitioners must be aware of the need to balance the alignment and enabling of the internal and external innovation environments – only then can innovation actions and the environment work synergistically.

Developing clarity regarding the potential of digital innovation for sustainability: Chapter 5 demonstrates the importance of understanding the solution space for different types of digital innovations for sustainability. This also has critical implications for practitioners aiming at digital innovation for sustainability.

For practitioners, this dissertation demonstrates the diverse opportunities of digital innovations to drive sustainable development. For example, LLMs and crowdsourcing can support idea

selection, while digital apps and information campaigns can increase adoption rates of scaled innovations. However, organizations can only leverage some of the different opportunities simultaneously. Thus, organizations need to invest in understanding their leverage points for improving their sustainability performance, the opportunities of various types of innovations, and how both potentially match together in the form of digital innovation for sustainability. Better clarity regarding the individual organizational opportunity space enables a more focused innovation endeavor where resources are targeted and prioritized according to the organization's needs. However, this does not imply that practitioners should not be open to new ideas or digital innovations. Instead, an ongoing assessment of existing and emerging digital opportunities against the organization's needs is the basis for balancing creativity and resource scarcity.

Balance emerges as an overarching task for practitioners across the dissertation's chapters. Balancing counterparts such as actions and environments, alignment and enablement, or creativity and focus is critical for leveraging the sustainability value of digital innovations.

7.4 Limitations and Outlook for Future Research

The chapters of this dissertation provide contributions to theory and practice, both individually and on a meta-level. However, there are also limitations to the research, and these provide fruitful pathways for future research. On a chapter level, the specific limitations and an outlook for future research are detailed at the end of each chapter. In the case of Chapter 6, one of its core contributions is the derivation of fundamental research pathways for DSI through a structured literature review. These pathways present a comprehensive outlook for future research. Building on the insights generated in Chapter 6, three overarching limitations of this dissertation that simultaneously highlight important areas for future research are presented in the following paragraphs.

Shift from theory building to theory testing: On a methodological plane, this dissertation applies both qualitative and quantitative approaches. The resulting mixed-methods approach allows for integration of the advantages of both approaches and the derivation of meta-inferences (Remenyi & Williams, 1996; Venkatesh et al., 2013; Wilde & Hess, 2007). In total, this dissertation has more qualitative components (Subchapters 3.1, 3.2, 4.1. 4.2, 5, and 6) than quantitative components (Subchapters 3.1 and 4.2).

In general, qualitative approaches are particularly suitable for phenomena that are relatively new as they allow for identification of the relevant constructs and relationships surrounding that phenomenon (Kaplan & Maxwell, 2005). The concept of digital innovation for sustainability is not yet widely established in IS research. Therefore, a focus on qualitative methodologies such as interview studies or literature reviews is appropriate to conceptualize digital innovation actions, environments, and outcomes and to build theories. However, with the rising maturity of the field, qualitative approaches impose limitations regarding the results' generalizability and predictive power (Gregor, 2006) as theory testing becomes more relevant. For example, Subchapter 3.2 presents the recurring change patterns observable in DTs and the role of digital innovation therein. The results create a better understanding of the type and nature of change in DTs. The selected qualitative approach, however, does not allow for drawing conclusions on the numerical importance or effectiveness of the different change patterns. Such insights, as well as confirmatory testing of the propositions from qualitative research, could only be yielded through quantitative approaches. Similarly, the exact impact of smart urban agriculture readiness factors in Chapter 5 on SUA success cannot be measured qualitatively.

For future research, this limitation calls for a quantitative perspective on the research questions posed in all chapters. For example, survey studies could be included to test the effect of change patterns, readiness factors, or the effectiveness of the different technostress prevention measures identified in Subchapter 4.1. Longitudinal studies that measure, for example, technostress levels at different time points while monitoring which prevention measures have been implemented could be another such extension (Remenyi & Williams, 1996; Wilde & Hess, 2007). Generally, this limitation also highlights the value of combining both approaches (i.e., qualitative and quantitative) in future research on digital innovation for sustainability.

Behavioral versus design-oriented research paradigms: As extensively discussed in Subchapter 2.3, this dissertation follows the behavioral science paradigm and strives to improve understanding of the dynamics in digital innovation for sustainability (Hevner et al., 2004; March & Smith, 1995). This scope was selected deliberately to first build a sound conceptual understanding of the research phenomenon. The limitations of the behavioral science paradigm are relatively straightforward. The contributions of this dissertation span theories for analyzing, explaining, and predicting, but they cannot yield level-five theories for design and action (Gregor, 2006). The design science research paradigm is necessary to develop this type of theory (Baskerville et al., 2018; Gregor, 2006).

For theory and practice, theories for design and action provide prescriptive knowledge with clear instructions on developing technological artifacts (Gregor & Hevner, 2013). In the context of this dissertation, theories for design and action could relate to artifacts in the form of digital innovations for sustainability. An extension of design science research could further ease the exploitation of sustainability value through digital innovations. For example, the results in Subchapter 3.1 regarding the potential of LLMs and crowdsourcing in idea evaluation could be used to develop design principles for an idea evaluation system. Following this path will extend knowledge on understanding digital innovation for sustainability toward actionable recommendations.

Synergies and conflicts between sustainability areas: A limitation also exists regarding the scope of this dissertation. The chapters differ regarding their specificity to particular areas of sustainability. Subchapter 3.1 deals with environmental sustainability, 3.2 with economic sustainability, 4.1 with social sustainability, and 4.2 with environmental sustainability, while Chapters 5 and 6 address all three pillars of sustainability. This heterogeneity in sustainability targets leads to two limitations.

First, some results are only valid within the respective pillar of sustainability and cannot easily be generalized to the other two. For example, the impact factors driving the adoption of TGRS identified in Subchapter 4.2 are partly specific to environmental sustainability (e.g., environmental norms). Therefore, the question of whether adoption impact factors for driving sustainable behavior in terms of social or economic sustainability are different remains open. This limits the transferability of the insights to other sustainability challenges. Second, this dissertation does not extensively cover potential synergies or conflicts between the sustainability pillars. Sometimes, achievements for one pillar of sustainability can lead to negative or positive developments in one of the other two pillars. In Subchapter 3.1, LLMs and crowdsourcing are highlighted as potential tools for driving the creation of environmental sustainability value. However, while this is undoubtedly positive for the pillar of environmental sustainability, there are certain risks for social sustainability. Integrating novel digital innovations bears the risk of, for example, discriminating against employees who are less digitally skilled and integrating potential biases of automated systems such as LLMs without recognizing the bias.

For future research, this limitation calls for a detailed assessment of recurring synergies and conflicts between and within the different pillars as well as of the role of digital innovations in

fostering or hindering these synergies and conflicts. In addition, it also underscores the importance of critically considering the transferability of research results to all three pillars, even in studies focusing explicitly only on one pillar.

7.5 Conclusion

Our world faces many sustainability challenges that appear complex, intertwined, and almost impossible to solve (Lönngren & van Poeck, 2021; Peters, 2017). Be it economic issues such as a rising income gap between the world's richest and poorest (Aguiar & Bils, 2015), social issues such as gender inequality or pandemics (Angeler et al., 2022; Gorbacheva & Barann, 2017), or environmental issues such as climate change threatening our natural world (Auffhammer, 2022), finding the right solutions is a task that requires collective global action (Head, 2008). Both the creative power of innovation to develop new ideas and the rise of digital technologies offer the potential to address the challenges mentioned above in novel, promising ways (Omri, 2020; Skare & Porada-Rochon, 2022). Therefore, leveraging digital innovation for sustainability is the focus of this dissertation.

Building on the IS community's calls to become involved with topics of sustainability (Malhotra et al., 2013; Melville, 2010), this dissertation drives the theoretical understanding of innovation actions, innovation environments, and innovation outcomes. For innovation actions, new insights on the necessary steps during innovation developments and the potential of digital innovations in traditional innovation are created. For innovation environments, both internal (e.g., employees) and external (e.g., customers) considerations are crucial to enable the ideation of promising ideas. Outcomes of digital innovation for sustainability can span products, services, processes, and even business models and focus on creating sustainability value. The interplay between technical and social aspects emerges as one of the central challenges for designing, implementing, and maintaining digital innovations that create sustainability value.

For organizations, this dissertation is a call to take responsibility for the many facets of sustainability impacted by their actions, including economic sustainability in terms of profitability, social sustainability in terms of employee and customer wellbeing, and environmental sustainability in terms of internal sustainable practices and the provision of sustainable products and services. Only when organizations, society, and policymakers work hand in hand to reach sustainable development can we achieve a fair world for all and leave enough for future generations.

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9 Appendix

Appendix A Analyzing the Potential of Crowdsourcing and Large Language Models in Innovation Contests

Appendix A.1 Large Language Model Prompt for Individual Idea Evaluations

Appendix A.1 presents the final prompt for one exemplary contest for requesting the LLM to provide an idea evaluation:

Please provide your evaluation in the standard format: [Five numbers separated by semicolons]

As an expert jury member in the semifinals of an idea contest with the topic "Shifting Attitudes and Behaviour" you evaluate 26 different proposals of which about half should make it to the final.

Please rate the proposal based on the criterion of novelty using a scale from 1 to 4, where 1 represents "Common, mundane, or boring", 2 stands for "Interesting, but not unheard of", 3 indicates "Unusual, interesting, and imaginative", and 4 signifies "Rare, surprising, challenging paradigms". You are allowed to answer in decimal numbers.

Please rate the proposal based on the criterion of feasibility using a scale from 1 to 4, where 1 represents "Infeasible socially, politically, legally or technically", 2 stands for "Challenging, feasibility is questionable", 3 indicates "Acceptable; Objections & barriers partially addressed", and 4 signifies "Appealing; Potential objections & barriers well addressed". You are allowed to answer in decimal numbers.

Please rate the proposal based on the criterion of impact using a scale from 1 to 4, where 1 represents "Benefits/ impact not clear", 2 stands for "Limited benefits/small impact", 3 indicates "Partial solution/ moderate impact", and 4 signifies "Large, direct, & positive impact". You are allowed to answer in decimal numbers.

Please rate the proposal based on the criterion of presentation using a scale from 1 to 4, where 1 represents "Neither clear, persuasive nor appealing", 2 stands for "Only one of the following three applies: Clear, Persuasive, Appealing", 3 indicates "Only two of the following three

apply: Clear, Persuasive, Appealing", and 4 signifies "All three of the following three apply: Clear, Persuasive, Appealing". You are allowed to answer in decimal numbers.

Given the quality of the proposal and the rating you scored on all four criteria, do you think the idea should advance to the final round (Advance-Score)? Please answer this question using a scale from 1 to 4 where 1 represents "Absolutely no", 2 indicates "rather no", 3 stands for "rather yes" and 4 signifies "absolutely yes". You are allowed to answer in decimal numbers.

Please provide your rating in the following row, divided by a semicolon: "Novelty of the proposal"; "Feasability of the proposal"; "Impact of the proposal"; "Presentation of the proposal"; "Advance-Score of the Proposal". So only provide five numbers divided by a semicolon without written text.

In the next section you can find the proposal.

[Proposal text]

Appendix A.2 Large Language Model Prompt for Pairwise Comparison

Appendix A.2 presents the final prompt for one exemplary contest for requesting the LLM to provide a pairwise comparison:

Please provide your evaluation in the standard format: [Nine numbers separated by semicolons]

As an expert jury member in the semifinals of an idea contest with the topic "Adaptation" you evaluate 2 different proposals.

Please rate both proposals based on the criterion of novelty using a scale from 1 to 4, where 1 represents "Common, mundane, or boring", 2 stands for "Interesting, but not unheard of", 3 indicates "Unusual, interesting, and imaginative", and 4 signifies "Rare, surprising, challenging paradigms". You are allowed to answer in decimal numbers.

Please rate both proposals based on the criterion of feasibility using a scale from 1 to 4, where 1 represents "Infeasible socially, politically, legally or technically", 2 stands for "Challenging, feasibility is questionable", 3 indicates "Acceptable; Objections & barriers partially addressed", and 4 signifies "Appealing; Potential objections & barriers well addressed". You are allowed to answer in decimal numbers.

Please rate both proposals based on the criterion of impact using a scale from 1 to 4, where 1 represents "Benefits/ impact not clear", 2 stands for "Limited benefits/small impact", 3 indicates "Partial solution/ moderate impact", and 4 signifies "Large, direct, & positive impact". You are allowed to answer in decimal numbers.

Please rate both proposals based on the criterion of presentation using a scale from 1 to 4, where 1 represents "Neither clear, persuasive nor appealing", 2 stands for "Only one of the following three applies: Clear, Persuasive, Appealing", 3 indicates "Only two of the following three apply: Clear, Persuasive, Appealing", and 4 signifies "All three of the following three apply: Clear, Persuasive, Appealing". You are allowed to answer in decimal numbers.

Given the quality of the proposals and the rating you scored on all four criteria, which of the two proposals should advance to the final round?

Please provide your rating in the following row, divided by a semicolon: "Novelty of the first proposal"; "Feasability of the first proposal"; "Impact of the first proposal"; "Presentation of the first proposal"; "Novelty of the second proposal"; "Feasability of the second proposal";

“Impact of the second proposal”; “Presentation of the second proposal”; “seven figure number of proposal that advances”. So only provide nine numbers divided by a semicolon without written text.

In the next two sections you can find the two proposals. Each section starts with the seven-figure number of the proposal:

[Proposal text]

Appendix B Understanding Change in Digital Transformation

Appendix B.1 Structured Literature Review on Digital Transformation

Appendix B.1 provides a detailed description of the five stages (i.e., define, search, select, analyze, and present) of the structured literature review (vom Brocke et al., 2015; Wolfswinkel et al., 2013).

(1) **Define:**

- *Research question:* How does organizational change unfold within and across different levels of analysis in the context of digital transformation?
- *Primary goal:* The main goals are to understand *what* changes in the context of digital transformation within and across levels of analysis, and to theorize about *how* change occurs from an intra- and inter-level perspective
- *Field of research:* IS Domain
- *Sources:* To include relevant research insights on organizational change in DT with a focus on both theory and practice, we systematically examined IS literature from three vantage points: (1) high scientific rigor, (2) broad dissemination, and (3) renowned industry influence. Therefore, we included the following data sources: Senior Scholars' List of Premier Journals (for high scientific rigor), AIS eLibrary (for broad dissemination), and Harvard Business Review and MIT Sloan Management Review (for renowned industry influence).
- *Inclusion/exclusion criteria:* We set the following inclusion/exclusion criteria (Table 24):

Inclusion Criteria	Exclusion Criteria
The study focuses on digital transformation.	The study only refers to digital transformation to motivate the actual study purpose.
The study investigates change in an organizational context.	The study investigates change in a non-organizational context (e.g., politics, globalization).
The study refers to digital transformation as a socio-technical phenomenon.	The study has a purely technical focus on digital technologies (e.g., software development, hardware implementation) without addressing their impact on organizational change.
The study provides generalizable insights.	The study is highly sector-specific without offering insights or implications that can be generalized to other organizational contexts.

Table 24: Overview of Inclusion and Exclusion Criteria

- *Further limitations:* Further limitations in the selection of literature were made by selecting only peer-reviewed articles in the AIS eLibrary and English as the only language. We had to restrict our sources due to a natural limitation of scope. Therefore, we decided against including, for example, ScienceDirect or Web of Science as additional sources beneath the AIS eLibrary.
- *Search string:* To capture all relevant publications, we chose the simple search string *"digital transformation"* and applied it to the topic search (title, keyword, abstract) with no restriction to the timeframe (vom Brocke et al., 2015).

(2) **Search:** In the second step, we used the previously defined criteria and applied the search string to filter the selected literature. We initially obtained 314 articles, of which 120 articles originate from the Senior Scholars' List of Premier Journals, 153 articles from the AIS eLibrary, and 41 articles from Harvard Business Review / MIT Sloan Management Review.

(3) **Select:** A qualitative filtering process best describes the third step, in which we conducted several screening techniques to further narrow our scope of articles (vom Brocke et al., 2015; Webster & Watson, 2002). After checking for duplets, we derived a data set of 275 articles. Next, we used a four-point Likert scale to form categories among the 275 articles depending on their relevance and focus on organizational change in DT, by reading the title and abstract of all 275 articles. To category one, we allocated all literature with a strong focus on organizational change in DT and the

research question. To category two, we assigned all articles with an average focus on organizational change in DT and the research question. Category three comprises those articles, which had a weak link to organizational change in DT and our research question but were questionable. The less relevant articles with no focus on organizational change in DT and our research question were allocated to category four and were immediately sorted out. Articles with a score of two or three were double-checked by another author and independently scored from one to four. Articles that were previously scored with a two (ascending trend) and by the second author with either a one, two, or three received the final score of one and stayed in the sample. Articles scored with a four were discussed within the author team and either assigned to one or four. Articles that were previously scored with a three (descending trend) and now received a two, three, or four received a final score of four and were sorted out. Articles, where the first author ranked with a three and the second author with a one, were discussed individually in the author team and after-ward received the final score of one or four. After the iterative filter process, we received our final data set of 142 articles to analyze in-depth (including 16 articles from forward/ backward search).

(4) **Analyze:** To ensure qualitative rigor in inductive research, we followed the analysis approach by Gioia et al. (2013). The coding steps are described in detail in Subchapter 3.2.2. We analyzed the literature using the qualitative data-analysis tool MAXQDA. The use of supporting software is widely approved and beneficial for literature reviews (Bandara et al., 2015).

(5) **Present:** We present the findings of our structured literature review in Subchapter 3.2.3 and discuss them in Subchapter 3.2.4**.**

Appendix B.2 Full Literature Sample for Digital Transformation

Appendix B.2 presents the set of 142 papers that were included in the full-text analysis and coding as part of the structured literature review. The table details the authors, the type of article (i.e., one of the three perspectives taken in the literature review), and the title.

#	Author	Type	Title
1	Agarwal et al. (2010)	Senior Scholars' List of Premier Journals	The Digital Transformation of Healthcare: Current Status and the Road Ahead
2	Agarwal et al. (2011)	AIS eLibrary	Leadership in the Face of Technological Discontinuities: The Transformation of EarthColor
3	Akram and Akesson (2011)	AIS eLibrary	Value Network Transformation By Digital Service Innovation in The Vehicle Industry
4	Andal-Ancion et al. (2003)	Industry-focused Journal	The Digital Transformation of Traditional Business
5	Andriole (2017)	Industry-focused Journal	Five Myths About Digital Transformation
6	Arakji and Lang (2007)	Senior Scholars' List of Premier Journals	Digital consumer networks and producer-consumer collaboration: Innovation and product development in the video game industry
7	Baculard (2017)	Industry-focused Journal	To Lead a Digital Transformation, CEOs Must Prioritize
8	Baiyere et al. (2021)	Senior Scholars' List of Premier Journals	Digital transformation and the new logics of business process management
9	Baptista et al. (2020)	Senior Scholars' List of Premier Journals	Digital work and organizational transformation: Emergent Digital/Human work configurations in modern organizations
10	Barthel and Hess (2020)	AIS eLibrary	Towards a Characterization of Digitalization Projects in the Context of Organizational Transformation
11	Bendig et al. (2022)	Senior Scholars' List of Premier Journals	When and why technology leadership enters the C-suite: An antecedents perspective on CIO presence

#	Author	Type	Title
12	Benitez et al. (2023)	Senior Scholars' List of Premier Journals	How have firms transformed and executed IT-enabled remote work initiatives during the COVID-19 pandemic? Conceptualization and empirical evidence from Spain
13	Benlian and Haffke (2016)	Senior Scholars' List of Premier Journals	Does mutuality matter? Examining the bilateral nature and effects of CEO-CIO mutual understanding
14	S. Berger et al. (2020)	AIS eLibrary/ Forward/Backward Search	Approaching Digital Transformation – Development of a multi-dimensional Maturity Model
15	S. Berger et al. (2018)	AIS eLibrary	The Nature of Digital Technologies – Development of a Multi-layer Taxonomy
16	Besson and Rowe (2012)	Senior Scholars' List of Premier Journals/ Forward/Backward Search	Strategizing information systems-enabled organizational transformation: A transdisciplinary review and new directions
17	Bharadwaj et al. (2013)	Senior Scholars' List of Premier Journals/ Forward/Backward Search	Digital Business Strategy: Toward a Next Generation of Insights
18	Bonnet and Westerman (2021)	Industry-focused Journal	The New Elements of Digital Transformation
19	Braojos et al. (2024)	Senior Scholars' List of Premier Journals	Empowering organizational commitment through digital transformation capabilities: The role of digital leadership and a continuous learning environment
20	Brünker et al. (2023)	Senior Scholars' List of Premier Journals	Proactive digital workplace transformation: Unpacking identity change mechanisms in remote-first organizations
21	Burden et al. (2018)	Industry-focused Journal	Technical Debt Might Be Hindering Your Digital Transformation
22	Case et al. (2019)	AIS eLibrary	Teaching Information Systems in the Age of Digital Disruption
23	Chanias et al. (2019)	Senior Scholars' List of Premier Journals	Digital transformation strategy making in pre-digital organizations: The case of a financial services provider
24	S. Chen and King (2022)	Senior Scholars' List of Premier Journals	Policy and Imprecise Concepts: The Case of Digital Transformation

#	Author	Type	Title
25	K.-L. Chen et al. (2023)	Senior Scholars' List of Premier Journals	Exploring the value of IoT data as an enabler of the transformation towards servitization: an action design research approach
26	Y.-J. Cheng et al. (2021)	Industry-focused Journal	Is Your C-Suite Equipped to Lead a Digital Transformation?
27	Chowdhury and Åkesson (2011)	AIS eLibrary	A Proposed Conceptual Framework For Identifying The Logic Of Digital Services
28	Dang and Vartiainen (2020)	AIS eLibrary/ Forward/Backward Search	Changing Patterns in the Process of Digital Transformation Initiative in Established Firms: The Case of an Energy Sector Company
29	Datta (2020)	AIS eLibrary	Digital Transformation of the Italian Public Administration: A Case Study
30	Davenport and Redman (2020)	Industry-focused Journal	Digital Transformation Comes Down to Talent in 4 Key Areas
31	Davenport and Spanyi (2019)	Industry-focused Journal	Digital Transformation Should Start With Customers
32	Demlehner and Laumer (2020)	AIS eLibrary	Why Context Matters: Explaining the Digital Transformation of the Manufacturing Industry and the Role of the Industry's Characteristics
33	Dery et al. (2017)	AIS eLibrary	The Digital Workplace is Key to Digital Innovation
34	Drechsler et al. (2020)	AIS eLibrary	At the Crossroads between Digital Innovation and Digital Transformation
35	Dremel et al. (2017)	AIS eLibrary	How AUDI AG Established Big Data Analytics in its Digital Transformation
36	Du et al. (2016)	AIS eLibrary	IT-enabled Slack Redeployment in a Latecomer Company
37	Eden et al. (2019)	AIS eLibrary	Digital Transformation Requires Workforce Transformation
38	Eikebrokk and Olsen (2020)	AIS eLibrary	Towards a Process Theory of IS Business Value Co-creation
39	T. Fischer et al. (2020)	AIS eLibrary	Coping with Rapid Changes in IT: An Update

#	Author	Type	Title
40	L. H. Fischer and Baskerville (2023)	Senior Scholars' List of Premier Journals	Explaining sociotechnical change: an unstable equilibrium perspective
41	Fitzgerald et al. (2013)	Industry-focused Journal	Embracing Digital Technology: A New Strategic Imperative
42	Frankiewicz and Chamorro-Premuzic (2020)	Industry-focused Journal	Digital Transformation Is About Talent, Not Technology
43	Fuchs and Hess (2018)	AIS eLibrary	Becoming Agile in the Digital Transformation: The Process of a Large Scale Agile Transformation
44	Furr et al. (2019)	Industry-focused Journal	Don't Put a Digital Expert in Charge of Your Digital Transformation
45	Gill and VanBoskirk (2016)	AIS eLibrary	The Digital Maturity Model 4.0
46	Gimpel, Hosseini, et al. (2018)	AIS eLibrary	Structuring Digital Transformation: A Framework of Action Fields and its Application at ZEISS
47	Govindarajan and Immelt (2019)	Industry-focused Journal	The Only Way Manufacturers Can Survive
48	Gregersen (2018)	Industry-focused Journal	Digital Transformation Opens New Questions — and New Problems to Solve
49	Gregory et al. (2018)	Senior Scholars' List of Premier Journals	IT Consumerization and the Transformation of IT Governance
50	Gurbaxani and Dunkle (2019)	AIS eLibrary	Gearing Up For Successful Digital Transformation
51	Haffke et al. (2017)	AIS eLibrary	Options for Transforming the IT Function Using Bimodal IT
52	Hanelt, Bohnsack, et al. (2021)	Forward/Backward Search	A Systematic Review of the Literature on Digital Transformation: Insights and Implications for Strategy and Organizational Change
53	Hansen and Kien (2015)	AIS eLibrary	Hummel's Digital Transformation Toward Omnichannel Retailing: Key Lessons Learned
54	Henretta and Chopra-McGowan (2017)	Industry-focused Journal	5 Ways to Help Employees Keep Up with Digital Transformation

#	Author	Type	Title
55	Hess et al. (2016)	AIS eLibrary	Options for Formulating a Digital Transformation Strategy
56	Hinings et al. (2018)	Senior Scholars' List of Premier Journals	Digital innovation and transformation: An institutional perspective
57	Hinsen et al. (2019)	Forward/Backward Search	Disentangling the Concept and Role of Continuous Change for IS Research – A Systematic Literature Review
58	Hoblos et al. (2023)	Senior Scholars' List of Premier Journals	Achieving stakeholder alignment in digital transformation: A frame transformation perspective
59	S. Huang et al. (2024)	Senior Scholars' List of Premier Journals	A configurational theory of digital disruption
60	Ives et al. (2016)	AIS eLibrary	Enhancing Customer Service through the Internet of Things and Digital Data Streams
61	Jensen (2018)	AIS eLibrary	Digital Transformation of Work
62	Jöhnk et al. (2022)	Forward/Backward Search	Managing the complexity of digital transformation — How multiple concurrent initiatives foster hybrid ambidexterity
63	Kaganer et al. (2023)	Senior Scholars' List of Premier Journals	A Process for Managing Digital Transformation: An Organizational Inertia Perspective
64	Kane (2017a)	Industry-focused Journal	Are You Taking the Wrong Approach to Digital Transformation?
65	Kane (2017b)	Industry-focused Journal	Digital Maturity, Not Digital Transformation
66	Kane (2017c)	Industry-focused Journal	Digital Transformation Is a Misnomer
67	Kane (2017d)	Industry-focused Journal	Don't Forget the Basics in Digital Transformation
68	Kane et al. (2015)	Industry-focused Journal	Strategy, Not Technology, Drives Digital Transformation
69	Kappelman et al. (2019)	Senior Scholars' List of Premier Journals	A study of information systems issues, practices, and leadership in Europe
70	Karimi and Walter (2015)	Senior Scholars' List of Premier Journals	The Role of Dynamic Capabilities in Responding to Digital Disruption: A

#	Author	Type	Title
			Factor-Based Study of the Newspaper Industry
71	Kauffman and Weber (2018)	Senior Scholars' List of Premier Journals	Special Section: The Digital Transformation of Vertical Organizational Relationships
72	Lanamäki et al. (2020)	Senior Scholars' List of Premier Journals	Examining relational digital transformation through the unfolding of local practices of the Finnish taxi industry
73	Lauterbach et al. (2020)	Senior Scholars' List of Premier Journals	Achieving Effective Use When Digitalizing Work: The Role of Representational Complexity
74	J. Y. H. Lee et al. (2020)	Senior Scholars' List of Premier Journals/ Forward/Backward Search	What Lies Beneath: Unraveling the Generative Mechanisms of Smart Technology and Service Design
75	Legner et al. (2017)	AIS eLibrary/ Forward/Backward Search	Digitalization: Opportunity and Challenge for the Business and Information Systems Engineering Community
76	Leinwand and Mani (2021)	Industry-focused Journal	Digitizing Isn't the Same as Digital Transformation
77	Liang Li et al. (2018)	Senior Scholars' List of Premier Journals	Digital transformation by SME entrepreneurs: A capability perspective
78	Libert et al. (2016a)	Industry-focused Journal	7 Questions to Ask Before Your Next Digital Transformation
79	Libert et al. (2016b)	Industry-focused Journal	How to Navigate a Digital Transformation
80	Mädche (2016)	AIS eLibrary	Interview with Michael Nilles on "What Makes Leaders Successful in the Age of the Digital Transformation?
81	J. Magnusson et al. (2020)	Senior Scholars' List of Premier Journals/ Forward/Backward Search	Efficiency creep and shadow innovation: enacting ambidextrous IT Governance in the public sector
82	Majchrzak et al. (2016)	Senior Scholars' List of Premier Journals	Designing for digital transformation: lessons for information systems research from the study of ICT and societal challenges
83	Mann et al. (2022)	Senior Scholars' List of Premier Journals	Orchestrating the digital transformation of a business ecosystem

#	Author	Type	Title
84	Matt et al. (2015)	AIS eLibrary	Digital Transformation Strategies
85	McConnell (2015)	Industry-focused Journal	The Company Cultures That Help (or Hinder) Digital Transformation
86	McGrath and McManus (2020)	Industry-focused Journal	Discovery-Driven Digital Transformation
87	Michelman (2019)	Industry-focused Journal	Key Words for Digital Transformation
88	Morton et al. (2020)	Senior Scholars' List of Premier Journals/ Forward/Backward Search	The Digital Work of Strategists: Using Open Strategy for Organizational Transformation
89	Müller et al. (2019)	AIS eLibrary	Digital Innovation and Organizational Culture: The Case of a Danish Media Company
90	Nambisan et al. (2017)	Senior Scholars' List of Premier Journals/ Forward/Backward Search	Digital Entrepreneurship: Toward a Digital Technology Perspective of Entrepreneurship
91	Nambisan et al. (2019)	AIS eLibrary/ Forward/Backward Search	The Digital Transformation of Innovation and Entrepreneurship: Progress, Challenges and Key Themes
92	D. E. O'Leary and Storey (2020)	AIS eLibrary	Communications of the Association for Information Systems Discovering and Transforming Exhaust Data to Realize Managerial Value
93	Osmundsen et al. (2022)	Senior Scholars' List of Premier Journals	Familiarity with digital twin totality: Exploring the relation and perception of affordances through a Heideggerian perspective
94	Poláková-Kersten et al. (2023)	Senior Scholars' List of Premier Journals	Digital transformation in high-reliability organizations: A longitudinal study of the micro-foundations of failure
95	Piccoli et al. (2024)	Senior Scholars' List of Premier Journals	Digital transformation requires digital resource primacy: Clarification and future research directions
96	Porter and Heppelmann (2015)	Industry-focused Journal	How Smart, Connected Products Are Transforming Companies
97	Puthiyamadam (2017)	Industry-focused Journal	How the Meaning of Digital Transformation Has Evolved

#	Author	Type	Title
98	Rahrovani (2020)	Senior Scholars' List of Premier Journals	Platform drifting: When work digitalization hijacks its spirit
99	Reinhold and Alt (2009)	AIS eLibrary	Enhancing Collaborative CRM With Mobile Technologies
100	Rickards and Grossman (2017)	Industry-focused Journal	The Board Directors You Need for a Digital Transformation
101	Riera and Iijima (2019)	AIS eLibrary	The Role of IT and Organizational Capabilities on Digital Business Value
102	Rodriguez (2018)	Industry-focused Journal	Putting Customer Experience at the Center of Digital Transformation
103	Ross et al. (2016)	AIS eLibrary/ Forward/Backward Search	Designing and Executing Digital Strategies
104	Rossi et al. (2020)	Senior Scholars' List of Premier Journals	Balancing fluid and cemented routines in a digital workplace
105	Saldanha et al. (2020)	Senior Scholars' List of Premier Journals	Aligning Information Technology and Business: The Differential Effects of Alignment During Investment Planning, Delivery, and Change
106	Saliola and Islam (2020)	Industry-focused Journal	How to Harness the Digital Transformation of the Covid Era
107	J. E. Scott (2007)	AIS eLibrary	An e-Transformation Study Using the Technology–Organization–Environment Framework
108	S. Scott and Orlikowski (2022)	Senior Scholars' List of Premier Journals	The Digital Undertow: How the Corollary Effects of Digital Transformation Affect Industry Standards
109	Sebastian et al. (2017)	AIS eLibrary	How Big Old Companies Navigate Digital Transformation
110	Seo (2017)	Senior Scholars' List of Premier Journals	Digital Business Convergence and Emerging Contested Fields: A Conceptual Framework
111	A. Singh and Hess (2017)	AIS eLibrary	How Chief Digital Officers Promote the Digital Transformation of their Companies
112	Smith and Watson (2019)	AIS eLibrary	Digital Transformation at Carestream Health

#	Author	Type	Title
113	Soluk and Kammerlander (2021)	Senior Scholars' List of Premier Journals	Digital Transformation in Family-Owned Mittelstand Firms: A Dynamic Capabilities Perspective
114	Struijk et al. (2023)	Senior Scholars' List of Premier Journals	Navigating digital transformation through an information quality strategy: Evidence from a military organization
115	C. Sun et al. (2022)	Senior Scholars' List of Premier Journals	Predicting Stages in Omnichannel Path to Purchase: A Deep Learning Model
116	Syed et al. (2023)	Senior Scholars' List of Premier Journals	Control-style ambidexterity and information systems project performance: an expanded view of control activities
117	Tabrizi et al. (2019)	Industry-focused Journal	Digital Transformation Is Not About Technology
118	F. T. C. Tan et al. (2017)	AIS eLibrary	How GoGet CarShare's Product-Service System is Facilitating Collaborative Consumption
119	F. T. C. Tan et al. (2020)	Senior Scholars' List of Premier Journals	Digital transformation of business ecosystems: Evidence from the Korean pop industry
120	Tanniru et al. (2018)	AIS eLibrary	Hospital Leadership in Support of Digital Transformation
121	Teubner and Stockhinger (2020)	Senior Scholars' List of Premier Journals	Literature review: Understanding information systems strategy in the digital age
122	Toutaoui et al. (2022)	Senior Scholars' List of Premier Journals	Managing paradoxes in bi-modal information technology functions: A multi-case study
123	Tuunanen et al. (2019)	AIS eLibrary	From Digitalization to Cybernization: Delivering Value With Cybernized Services
124	van der Meulen et al. (2020)	AIS eLibrary	Managing Organizational Explosions During Digital Business Transformations
125	Vega and Chiasson (2019)	Senior Scholars' List of Premier Journals/Forward/Backward Search	A comprehensive framework to research digital innovation: The joint use of the systems of innovation and critical realism

#	Author	Type	Title
126	Vial (2019)	Senior Scholars' List of Premier Journals	Understanding digital transformation: A review and a research agenda
127	Walker (2020)	Industry-focused Journal	Rethinking Digital Transformation
128	Warner and Wäger (2019)	AIS eLibrary/ Forward/Backward Search	Building Dynamic Capabilities for Digital Transformation: An Ongoing Process of Strategic Renewal
129	Weritz et al. (2024)	Senior Scholars' List of Premier Journals	Impact of strategic capabilities on digital transformation success and firm performance: theory and empirical evidence
130	Wessel et al. (2021)	Senior Scholars' List of Premier Journals	Unpacking the Difference Between Digital Transformation and IT-Enabled Organizational Transformation
131	Westerman (2016)	Industry-focused Journal	Why Digital Transformation Needs a Heart
132	Westerman and Bonnet (2015)	Industry-focused Journal	Revamping Your Business Through Digital Transformation
133	Westerman et al. (2014)	Industry-focused Journal	The Nine Elements of Digital Transformation
134	Westerman et al. (2019)	Industry-focused Journal	Building Digital-Ready Culture in Traditional Organizations
135	Whitehurst (2015)	Industry-focused Journal	Driving Digital Transformation: New Skills for Leaders, New Role for the CIO
136	Wiedemann et al. (2023)	Senior Scholars' List of Premier Journals	Integrating development and operations teams: A control approach for DevOps
137	Wiesböck et al. (2020)	Senior Scholars' List of Premier Journals	The dual role of IT capabilities in the development of digital products and services
138	Wimelius et al. (2021)	Senior Scholars' List of Premier Journals	A Paradoxical Perspective on Technology Renewal in Digital Transformation
139	T. J. Winkler and Kettunen (2018)	AIS eLibrary	Five Principles of Industrialized Transformation for Successfully Building an Operational Backbone
140	Wulf et al. (2017)	AIS eLibrary	Using a Digital Services Capability Model to Assess Readiness for the Digital Consumer

#	Author	Type	Title
141	Zhu et al. (2006)	Senior Scholars' List of Premier Journals	Innovation Diffusion in Global Contexts: Determinants of Post-adoption Digital Transformation of European Companies
142	Zimmer et al. (2023)	Senior Scholars' List of Premier Journals	Digital workplace transformation: Subtraction logic as deinstitutionalizing the taken-for-granted

Table 25: Overview of the Literature Sample on Digital Transformation

Appendix B.3 Final Digital Transformation Data Structure after Coding

Appendix B.3 presents the final data structure yielded by the coding approach. Each table comprises the listing of all DT initiatives and patterns for one DT theme. In addition, exemplary references for each initiative and their assignment to episodic or continuous change are provided. The second column includes a "C" for continuous and an "E" for episodic initiatives.

Exemplary Reference	**Episodic/ Continuous**	**DT Initiative**	**DT Pattern**
Barthel and Hess (2020)	C	Communicate cultural values that support a digital mindset.	Transforming from a change-reluctant culture to an entrepreneurial culture fully embracing change as an opportunity.
Dremel et al. (2017)	C	Communicate the value of data to create a data-driven culture.	
Agarwal et al. (2011)	C	Manage incentives for a hands-on startup mentality and out-of-the-box thinking.	
J. Magnusson et al. (2020)	C	Encourage a trial-and-error culture to foster experimentation.	
Rossi et al. (2020)	E	Develop a concept for ambidexterity to balance exploration and exploitation.	Transforming from a predominant focus on efficiency-oriented process improvements to including radical innovations.
Sebastian et al. (2017)	E	Establish a digital service platform and an operational backbone to enable both agility (i.e., rapid innovation) and efficiency (i.e., operational excellence).	
Toutaoui et al. (2022)	E	Establish bimodal IT by splitting the IT function into two modes (i.e., efficiency and innovation).	
Warner and Wäger (2019)	E	Develop tools for scaling promising business models quickly.	Transforming from sequential to iterative product and service development processes through rapid prototyping and experimentation.
Wiedemann et al. (2023)	C	Learn agile project management and product development methodologies (e.g., lean startup, SCRUM, DevOps).	
Vial (2019)	C	Use experimentation spaces for emerging technologies (e.g., blockchain, machine learning, virtual reality) to leverage first-mover advantages.	
Case et al. (2019)	C	Provide flexible and adaptable services through digital technologies (e.g., a specific device, connective networks, and data).	Transforming from isolated to concerted use of digital

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
J. Y. H. Lee et al. (2020)	C	Homogenize data in digital products to leverage the capabilities of other layers for different industries and user contexts.	technologies, which enables continuous adaptation and re-combination.

Table 26: Data for Fostering Digital Innovation

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Baiyere et al. (2020)	E	Redesign to autonomous and flexible decision-making processes to increase decision speed.	Transforming from a top-down culture to a culture that empowers individuals to become active members of DT.
Barthel and Hess (2020)	C	Foster autonomy in team selection and management to encourage employees to work with whoever is best suited for a situation or task.	
A. Singh and Hess (2017)	C	Involve employees in digital transformation through bottom-up approaches.	
Tanniru et al. (2018)	C	Provide employees with resources for digital transformation (e.g., budget, IT, human resources).	
Liang Li et al. (2018)	C	Provide experimental learning opportunities (e.g., hackathons, innovation competitions, job shadowing) to encourage hands-on learning and peer-to-peer mentoring.	Transforming from a focus on promoting employees' domain expertise to developing learning opportunities that promote digital literacy.
Wessel et al. (2021)	C	Provide employees with on-the-job experience, formal learning (e.g., seminars), and informal learning (e.g., peer-to-peer learning).	
Lauterbach et al. (2020)	C	Provide customized self-learning opportunities that are easily integrable in the daily routine (e.g., mobile learning).	
S. Berger et al. (2020)	C	Recruit external digital talent.	
Legner et al. (2017)	C	Provide trainings for digital skills and capabilities (e.g., market sensing and seizing, data analysis, or information sharing capabilities).	
Dremel et al. (2017)	C	Train the IT department to act as a digital coach and provide digital know-how.	
Vial (2019)	E	Hire a Chief Digital Officer to bridge the boundaries between business and IT.	Transforming from digital-agnostic leadership roles and responsibilities
Tanniru et al. (2018)	E	Hire an employee experience leader to optimize all employee touchpoints.	

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Braojos et al. (2024)	E	Build a digitally savvy leadership team combining experience with a fresh digital mindset.	to digital role models.
Baptista et al. (2020)	C	Communicate clear roles and responsibilities for all digital transformation efforts (e.g., data scientist).	
Kane (2017b)	C	Offer leadership trainings to create a charismatic leadership style that motivates employees for digital transformations.	
Dery et al. (2017)	C	Drive employee connectedness and employee bonding (e.g., social events) to enable collaboration and innovation within the organization.	Transforming from a narrow focus on the management of human resources to a broader focus that includes the promotion of active employee engagement.
Dremel et al. (2017)	C	Manage incentives for employees to successfully contribute to digital transformation (e.g., through bonus programs).	
Smith and Watson (2019)	C	Encourage bottom-up strategizing and collaborative vision-building activities.	
K.-L. Chen et al. (2023)	C	Communicate the urgency for change and the value of digital technologies (e.g., through success stories).	
Jensen (2018)	E	Design modern and flexible office concepts that combine spaces for creative collaboration and concentrated working.	Transforming from private office spaces to new work environments that modernize work design.
Benitez et al. (2023)	E	Design the physical office space in a hybrid-friendly way.	
Brünker et al. (2023)	E	Provide digital tools and platforms to employees (e.g., enterprise social media) to facilitate collaboration and networking inside and outside of the organization.	

Table 27: Data for Unfolding Employee Engagement

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Davenport and Redman (2020)	C	Perform data quality management (i.e., consistency, relevance, reliability).	Transforming from non-transparent data processing to active data protection through privacy-by-design.
J. Y. H. Lee et al. (2020)	C	Supervise data privacy and security during the collection, transfer, and use of personal data.	
Ives et al. (2016)	C	Perform data governance (i.e., policies, procedures, standards).	
Davenport and Spanyi (2019)	C	Analyze process data regarding improvement potential.	Transforming from intuition-based to data-based decision-making.
Lanamäki et al. (2020)	C	Gain real-time insights into customer behavior and proactively meet customer needs through highly personalized interactions and offerings.	
A. Singh and Hess (2017)	C	Predict future trends and develop strategic foresight (e.g., system failures, business opportunities) through data analytics.	
Warner and Wäger (2019)	E	Assess digital maturity to identify opportunities for improvement.	Transforming from ad-hoc implementation of digital technologies to deliberate planning of digital technology adoption.
Tanniru et al. (2018)	E	Establish benchmarks to decide how long a technology should be monitored and matured before jumping on a ‘technology hype’.	
Fitzgerald et al. (2013)	E	Establish KPIs to monitor digital business activities (e.g., customer retention, operational efficiency, employee satisfaction).	
Y.-J. Cheng et al. (2021)	C	Monitor the environment for potential trends and risks stemming from digital technologies.	
Hess et al. (2016)	C	Analyze and evaluate the potential impacts of digital technologies for business success.	

Table 28: Data for Integrating Technologies in Decision-making

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Saldanha et al. (2020)	E	Develop an integrated IT and business strategy.	Transforming from opportunistic approaches to DT to a clearly defined and aligned digital trans-formation strategy.
Soluk and Kammerlander (2021)	E	Create a digital transformation roadmap that prioritizes digital transformation initiatives.	
Ross et al. (2016)	E	Formulate an organization-wide digital strategy.	
Tabrizi et al. (2019)	E	Develop an overall vision on the long-term digital future.	
Fitzgerald et al. (2013)	C	Communicate digital transformation vision, strategy, and underlying goals actively.	
Matt et al. (2015)	C	Use learnings from previous transformation initiatives to finetune the digital strategy.	
Haffke et al. (2017)	E	Restructure the role of the IT department to promote proactiveness and innovativeness in exploring digital options and supporting transformation initiatives.	Transforming from functional silos into cross-functional collaboration and team-based structures.
Gregory et al. (2018)	E	Establish cross-functional leadership team structures to promote shared ownership of digital initiatives and balance power between departments.	
Dremel et al. (2017)	E	Establish a multidisciplinary competence network to cascade knowledge across the organization.	
Warner and Wäger (2019)	E	Design an interdisciplinary and cross-functional team structure with diverse skills and backgrounds.	
Chanias et al. (2019)	E	Establish a digital advisory board to support management with internal and external experts.	Transforming from distributed to centralized and aligned DT governance structures.
Kappelman et al. (2019)	E	Establish steering and executive committees to bundle digital transformation efforts and make key decisions about investments and resource allocations.	

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Hinings et al. (2018)	E	Establish a central digital business unit (e.g., digital innovation hub, digital factory) for innovation.	
Hess et al. (2016)	E	Create new revenue streams from digitized products, services, or business models (e.g., freemium, subscription revenue).	Transforming from fixed payment and ownership models to flexible revenue streams facilitated by digital service innovations and the sharing economy.
Ives et al. (2016)	C	Monetize data products to third parties.	
Demlehner and Laumer (2020)	C	Ideate value-added services and features to exploit post-sale revenues.	

Table 29: Data for Reorganizing Internal Structures

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
T. Fischer et al. (2020)	E	Establish a center of excellence for the acquisition of digital talent.	Transforming from passive to active recruiting that focuses on digital talent and expertise.
Haffke et al. (2017)	C	Conduct employer branding campaigns.	
Hess et al. (2016)	C	Collaborate with universities or research institutions to connect with digital natives early on.	
Mädche (2016)	C	Offer graduate trainee programs or dual (work & study) programs.	
Westerman (2016)	E	Assess the potential of outsourcing technological processes or digital transformation-related activities.	Transforming from a focus on internal capabilities to additionally embracing external resources.
F. T. C. Tan et al. (2020)	C	Source capabilities from external experts to acquire stronger digital competencies (e.g., consultancies, universities, startups).	
Teubner and Stockhinger (2020)	C	Exchange digital assets and IT resources with other firms in the business ecosystem to foster inter-organizational innovation.	
Wimelius et al. (2021)	C	Participate in knowledge sharing within and across the organization.	
Teubner and Stockhinger (2020)	E	Build a data lake where structured and unstructured data can be stored flexibly for advanced analytics.	Transforming from distributed internal data sources to integrating a variety of data sources within and across organizational boundaries.
Du et al. (2016)	E	Build a data warehouse as the foundation for business intelligence functions.	
A. Singh and Hess (2017)	E	Deploy a data management platform to manage data lakes and data warehouses.	
Ross et al. (2016)	C	Access a variety of internal and external data sources (e.g., sensors, social media, third party) for data analytics.	
J. Y. H. Lee et al. (2020)	C	Collect both historical and real-time data sets to avoid innovation latency.	

Table 30: Data for Managing Digital Capabilities

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Sebastian et al. (2017)	E	Develop a customer-facing digital service platform for digital customer services.	Transforming from product- and technology-focused to business- and customer-focused value propositions.
Dery et al. (2017)	E	Digitize all touchpoints (incl. sales and distribution channels) along the customer journey.	
Gill and VanBoskirk (2016)	C	Apply customer analysis tools (e.g., personas, journey maps) to align product and service design with the expectations of the customer.	
Chanias et al. (2019)	C	Integrate consumer-centric innovation methods (e.g., design thinking).	
Gregory et al. (2018)	C	Work with a multi-to-omnichannel approach by combining offline and online channels.	
A. Singh and Hess (2017)	C	Combine products with additional digital services.	Transforming from physical to digitally enriched offerings with a focus on digital service innovations.
K.-L. Chen et al. (2023)	C	Focus on digital service innovation to increase customer engagement.	
Wessel et al. (2021)	C	Assess the integration of technological components (e.g., sensors) in existing products.	

Table 31: Data for Reshaping Customer Value

Exemplary Reference	Episodic/ Continuous	DT Initiative	DT Pattern
Vial (2019)	C	Leverage new forms of innovation (e.g., open innovation) to co-develop within the digital ecosystem.	Transforming from linear supply chains to highly connected value networks.
Leinwand and Mani (2021)	C	Collaborate within a digital ecosystem of strategic alliances.	
T. Fischer et al. (2020)	C	Involve users and customers in the innovation process.	
Teubner and Stockhinger (2020)	C	Manage incentives for stakeholders to participate in the digital ecosystems (e.g., sharing of knowledge and IT resources).	
Bharadwaj et al. (2013)	C	Invest in multi-sided business models.	
Gurbaxani and Dunkle (2019)	C	Experiment with sharing and collaborative consumption business models.	
Dery et al. (2017)	E	Establish cloud computing to provide secure, on-demand, and low-cost access to powerful computing resources.	Transforming from a function-specific organizational IT infrastructure to a flexible and modular IT infrastructure with high interoperability.
Baiyere et al. (2020)	E	Develop a concept for a flexible, scalable, and modular IT infrastructure.	
F. T. C. Tan et al. (2020)	E	Implement digital platforms to improve inter-organizational collaboration, product development, and data exchange.	
Vega and Chiasson (2019)	E	Define explicit regulations (e.g., clearly defined APIs) to balance open infrastructure demands with potential security risks.	
Baiyere et al. (2020)	E	Modularize and automate repetitive business processes to reduce system complexity.	
Teubner and Stockhinger (2020)	E	Redesign to flexible and modular processes to adapt quickly to shifting project priorities and customer demands.	
Dremel et al. (2017)	E	Conduct a systems integration project to link different tools and applications and reduce interfaces.	
Hinings et al. (2018)	C	Comply with process standards to enable interoperability and unify organization-wide procedures.	

Table 32: Data for Building Collaborative Ecosystems

Appendix C Developing Technostress Prevention Measures

Appendix C.1 Literature Review Process for Technostress Prevention

Appendix C.1 presents the process for searching and selecting technostress prevention literature.

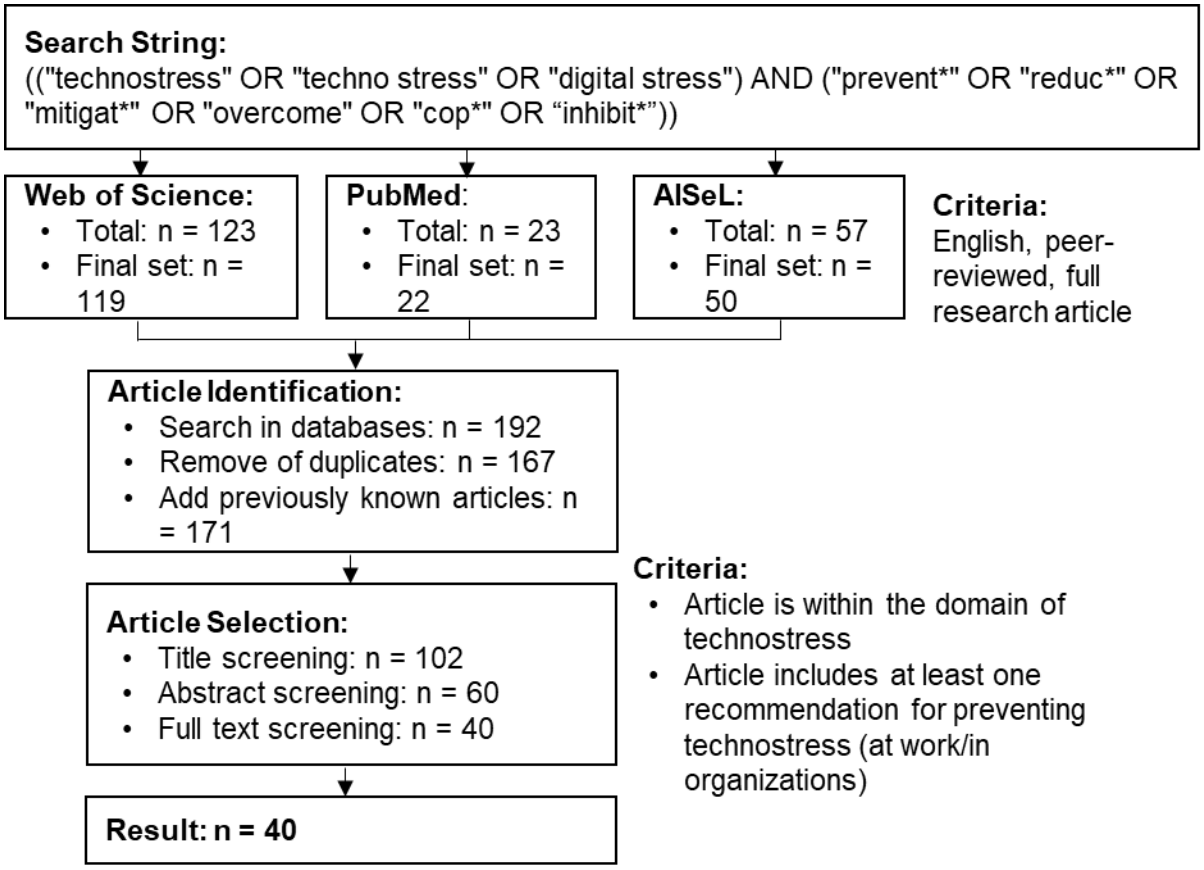

Figure 30: Literature Review Process for Technostress Prevention

Appendix C.2 Overview of Technostress Literature Review Results

Appendix C.2 presents the full list of studies analyzed in the process of extracting technostress prevention measures.

Study	**Context**	**Mentioned Potential Prevention Measures**	**Used as an Input for the Following Prevention Measures**
Bala and Venkatesh (2016)	Work-related technostress	Experiential engagements (user participation, training effectiveness) and psychological engagements (user involvement, management support)	(3) Apply human-centered release management (4) Apply human-centered ICT design (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (23) Provide ICT training
Chandra et al. (2019)	Technostress and employee innovation	Sensibilization, training, social support (mentor)	(16) Train mentors for digital topics (23) Provide ICT training (24) Foster sensitization and self-reflection regarding technostress
Fuglseth and Sørebø (2014)	Work-related technostress	Helpdesk, supportive leadership style, end-user training, user involvement, knowledge sharing	(3) Apply human-centered release management (19) Provide ICT support (11) Develop team norms for the use of ICTs (23) Provide ICT training (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (22) Offer platforms to exchange experience on ICT use
Ragu-Nathan et al. (2008)	Work-related technostress	Technical support provision, literacy facilitation, involvement facilitation	(3) Apply human-centered release management (4) Apply human-centered ICT design (6) Foster a cooperative culture (19) Provide ICT support (10) Consciously manage ICT-related change (23) Provide ICT training (15) Provide role models with technological changes
Tarafdar et al. (2010)	Work-related technostress	User involvement in the design of IS, support mechanisms for innovation	(3) Apply human-centered release management (4) Apply human-centered ICT design

Study	Context	Mentioned Potential Prevention Measures	Used as an Input for the Following Prevention Measures
Tarafdar et al. (2011)	Work-related technostress	Technical support provision, technology involvement facilitation, innovation support	(3) Apply human-centered release management (4) Apply human-centered ICT design (19) Provide ICT support
Tarafdar et al. (2015)	Work-related technostress	Self-efficacy, technical support (helpdesk), technology competence, user involvement	(3) Apply human-centered release management (19) Provide ICT support (23) Provide ICT training

Table 33: Result of the Literature Review (Technostress Inhibitor Articles)

Study	Context	Mentioned Potential Prevention Measures	Used as an Input for the Following Prevention Measures
Adam et al. (2017)	Work-related technostress	Stress-sensitive adaptive enterprise systems	(18) Provide supportive ICTs
Al-Fudail and Mellar (2008)	Technostress of teachers	Resources (reliable technology), social support (mentoring), technical support, IT training	(16) Train mentors for digital topics (19) Provide ICT support (23) Provide ICT training
Arnetz (1996)	Work-related technostress	Healthy and productive design of the workplace, training programs	(2) Adapt a stress-sensitive digital workplace design (23) Provide ICT training
Benlian (2020)	Technostress spillovers from work to home	Social support (coaching), facilitate employees' awareness of technostress through mentoring, supportive culture concerning accessibility, management leadership	(6) Foster a cooperative culture (7) Develop a mission statement for digital collaboration (13) Train managers to successfully lead in the digital working world (16) Train mentors for digital topics (24) Foster sensitization and self-reflection regarding technostress
Cao and Yu (2019)	Technostress through social media at work	Sensibilization and awareness to enable behavior changes for social media usage that is actively managed	(17) Train effective self-management and time management (24) Foster sensitization and self-reflection regarding technostress
Caro and Sethi (1985)	Work-related technostress	Technological planning, culture, technostress monitoring systems, self-development programs	(3) Apply human-centered release management (18) Provide supportive ICTs (6) Foster a cooperative culture (23) Provide ICT training
S. Carolan et al. (2017)	Work-related technostress	Discussion groups, time management, information on stress	(17) Train effective self-management and time management (22) Offer platforms to exchange experience on ICT use (24) Foster sensitization and self-reflection regarding technostress
J. V. Chen et al. (2019)	Technostress through mobile apps in leisure time	Sensibilization, self-reflection, time management, monotasking	(17) Train effective self-management and time management (20) Train monotasking (24) Foster sensitization and self-reflection regarding technostress
D'Arcy et al. (2014)	Security-related technostress	Helpdesk, awareness programs, education, and awareness security policies	(18) Provide supportive ICTs (6) Foster a cooperative culture (8) Introduce an employee data security concept (19) Provide ICT support

Study	Context	Mentioned Potential Prevention Measures	Used as an Input for the Following Prevention Measures
			(11) Develop team norms for the use of ICTs (23) Provide ICT training (24) Foster sensitization and self-reflection regarding technostress
Day et al. (2012)	Work-related technostress	Assistance like helpdesk, mentor, leader, culture, and clear communication guidelines	(18) Provide supportive ICTs (6) Foster a cooperative culture (7) Develop a mission statement for digital collaboration (19) Provide ICT support (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (16) Train mentors for digital topics
Delpechitre et al. (2019)	Salespeople's technostress	Increase self-efficacy	(23) Provide ICT training
Elie-Dit-Cosaque et al. (2011)	Work-related technostress	Top management support, supportive leadership style	(13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes
Galluch et al. (2015)	Work-related technostress	Timing control, method control, resource control	(11) Develop team norms for the use of ICTs (17) Train effective self-management and time management
Hung et al. (2015)	Personality and technostress	Proactive personality traits (training, self-reflection)	(24) Foster sensitization & self-reflection regarding technostress
Khedhaouria and Cucchi (2019)	Technostress of senior managers	Self-management, time-management, availability, supportive leadership style	(12) Establish reachability management (17) Train effective self-management and time-management (13) Train managers to successfully lead in the digital working world (20) Train monotasking
G. Kim and Kim (2014)	Work-related technostress	Supportive leadership style, helpdesk	(19) Provide ICT support (13) Train managers to successfully lead in the digital working world
Kloker (2020)	Technostress in daily lives	Situation management, gratification management, expectation management	(24) Foster sensitization and self-reflection regarding technostress
M.-S. Lee et al. (2015)	Technostress in general	Interaction with indoor plants	(2) Adapt a stress-sensitive digital workplace design
Manning et al. (2020)	Technostress of high school teacher	Trustful culture, leading style	(18) Provide supportive ICTs (6) Foster a cooperative culture (13) Train managers to successfully lead in the digital working world

Study	Context	Mentioned Potential Prevention Measures	Used as an Input for the Following Prevention Measures
Pfaffinger et al. (2020)	Work-related technostress	Expectation management, training, self-management, time-management, leadership style, helpdesk	(11) Develop team norms for the use of ICTs (19) Provide ICT support (12) Establish reachability management (23) Provide ICT training (17) Train effective self-management and time management (13) Train managers to successfully lead in the digital working world (14) Train managers for leading of distributed team members
Pirkkalainen et al. (2019)	Work-related technostress	Training to raise awareness, encourage self-reflection, and self-management	(4) Apply human-centered ICT design (23) Provide ICT training (24) Foster sensitization and self-reflection regarding technostress (17) Train effective self-management and time management
Revilla Munoz et al. (2016)	Technostress of Teachers	Support program	(19) Provide ICT support (22) Offer platforms to exchange experience on ICT use
Richter and Richter (2020)	Technostress of digital nomads	Expectation management	(7) Develop a mission statement for digital collaboration (11) Develop team norms for the use of ICTs
Saunders et al. (2017)	Techno-overload	Monotasking	(20) Train monotasking
Saxena and Lamest (2018)	Technostress on a business manager	Personal and organizational coping (supportive systems, monotasking, training, helpdesk)	(18) Provide supportive ICTs (7) Develop a mission statement for digital collaboration (19) Provide ICT support (17) Train effective self-management and time management (13) Train managers to successfully lead in the digital working world
Stich et al. (2019)	Technostress through E-mail Usage	Self-reflection on e-mail usage, expectation management concerning individual's preferences concerning e-mail overload	(7) Develop a mission statement for digital collaboration (11) Develop team norms for the use of ICTs (24) Foster sensitization and self-reflection regarding technostress
Tarafdar et al. (2007)	Work-related technostress	ICT training, communication about the need of ICT, leadership style, discussion forums	(23) Provide ICT training (13) Train managers to successfully lead in the digital working world (15) Provide role models with technological changes (22) Offer platforms to exchange experience on ICT use

Study	Context	Mentioned Potential Prevention Measures	Used as an Input for the Following Prevention Measures
Turel and Gaudioso (2018)	Work-related technostress	Supportive leadership style and culture with less competition	(6) Foster a cooperative culture (11) Develop team norms for the use of ICTs (13) Train managers to successfully lead in the digital working world
Weinert et al. (2020)	Individual perspective of technostress mitigation	Instrumental and social support	(19) Provide ICT support (16) Train mentors for digital topics
Weinstein et al. (2016)	Technostress in daily lives	Online discussion forums	(22) Offer platforms to exchange experience on ICT use
Wiholm et al. (2000)	Work-related technostress	Stress management training	(24) Foster sensitization and self-reflection regarding technostress (17) Train effective self-management and time management
Yu et al. (2017)	Technology adaption	Training, user involvement for selection of media, and the design of technology	(17) Train effective self-management and time management (23) Provide ICT training
Yun et al. (2012)	Office-home smartphones and technostress	Supportive culture to minimize work-to-life conflict and tools to support this	(6) Foster a cooperative culture (18) Provide supportive ICTs

Table 34: Result of the Literature Review (Further Related Technostress Articles)

Appendix C.3 Overview of Technostress Study Participants

Appendix C.3 details the participants of the technostress focus group workshops and the Delphi study.

Code	Role	Workshop
Part1	Researcher focusing on the digitalization of the workplace working for a German university	First
Part2	Head of human resources department in an SME focusing on customer acquisition and retention	First
Part3	Member of the works council working for a manufacturer of entertainment and communication technology with over 2,000 employees	First
Part4	An employee working for an SME focusing on customer acquisition and retention	First
Part5	Professor for business and information systems engineering at a German university	First
Part6	A person in charge of psychological risk assessments working for an occupational health management service provider responsible for over one million employees	Both
Part7	Consultant with a focus in working-time and work organization focusing on SME	Both
Part8	Psychologist and trainer working for an occupational health management service provider responsible for over one million employees	Both
Part9	An emergency psychologist working for an occupational health management service provider responsible for over one million employees	Second
Part10	A researcher with a focus in working-time and work organization at a federal institute focusing on occupational safety and health	Second

Table 35: Participants of the Focus Group Workshops

Code	Role
Exp1	Senior ombudsperson for severely disabled persons at an aircraft manufacturer responsible for health management
Exp2	Experienced employer representative working for the employers' association for a major industry in the country
Exp3	Occupational physician in the field of healthiness and well-being for a large workers' compensation company
Exp4	Former vice-chairman of a works council and lecturer at a training institute for works councils focusing among others on remote work and stress management
Exp5	Employee representative working for a national trade union center for a large trade union in the country
Exp6	Scientific director of a federal institute focusing on occupational safety and health management
Exp7	Senior researcher at an institute focusing on remote work and qualification
Exp8	Head of health management at the human resources department for a company in the construction industry
Exp9	Senior safety specialist at the human resources department for a company in the construction industry responsible for corporate health measures, among others stress management and remote work
Exp10	Occupational safety specialist at the human resources department for a company in the baking industry, responsible for stress management in the company
Exp11	Systemic consultant in and with organizations for a company in the baking industry regarding health and stress management
Exp12	Head of occupational safety at the human resources department for a company in the construction industry responsible for corporate health measures, among others during remote work
Exp13	26 years of experience with psychosocial counseling and psychological coaching for employees and managers in large companies as a social consultant with a focus on, e.g., work-life-balance, stress, remote working

Table 36: Delphi Study Panelists

Appendix C.4 Characterization of Technostress Prevention Measures

Appendix C.4 presents the detailed characterization of the technostress prevention measures.

#	Technostress Prevention Measure	Prevention Type	Entity of Change	Target Group	Organization Size	Implementation Duration	Realization Duration	Effect Duration
1	Focus the ICT landscape	Primary	Technology	All	Min. 50	1-3 years	Less than 0.5 years	1-3 years
2	Adapt a stress-sensitive digital workplace design	Primary	Technology	All	Min. 10	1-3 years	Less than 0.5 years	1-3 years
3	Apply human-centered release management	Primary	Technology	All	Min. 50	Less than 1 year	0.5-1 year	1-3 years
4	Apply human-centered ICT design	Primary	Technology	All	Min. 50	Less than 1 year	Less than 0.5 years	1-3 years
5	Use gamification	Primary	Technology	All	Min. 50	1-3 years	0.5-1 year	Less than 1 year
6	Foster a cooperative culture	Primary	Organization	All	Min. 50	1-3 years	More than 1 year	1-3 years
7	Develop a mission statement for digital collaboration	Primary	Organization	All	Min. 50	1-3 years	0.5-1 year	1-3 years
8	Introduce an employee data security concept	Primary	Organization	All	Min. 10	Less than 1 year	Less than 0.5 years	1-3 years
9	Agree on binding ICT usage guidelines	Primary	Organization	All	Min. 50	1-3 years	0.5-1 year	1-3 years
10	Consciously manage ICT-related change	Primary	Organization	All	Min. 50	1-3 years	0.5-1 year	1-3 years
11	Develop team norms for the use of ICTs	Primary	Organization	All	Min. 50	More than 3 years	Less than 0.5 years	1-3 years

#	Technostress Prevention Measure	Prevention Type	Entity of change	Target Group	Organization Size	Implementation Duration	Realization Duration	Effect Duration
12	Establish reachability management	Primary	Organization	All	Min. 10	Less than 1 year	0.5-1 year	Less than 1 year
13	Train managers to successfully lead in the digital working world	Primary	Individual	Mgmt.	Min. 50	1-3 years	0.5-1 year	1-3 years
14	Train managers for leading of distributed team members	Primary	Individual	Mgmt.	Min. 50	1-3 years	0.5-1 year	1-3 years
15	Provide role models with technological changes	Primary	Individual	Mgmt.	Min. 50	1-3 years	0.5-1 year	1-3 years
16	Train mentors for digital topics	Primary	Individual	All	Min. 250	Less than 1 year	Less than 0.5 years	1-3 years
17	Train effective self-management and time management	Primary	Individual	All	Min. 10	Less than 1 year	0.5-1 year	Less than 1 year
18	Provide supportive ICTs	Secondary	Technology	All	Min. 10	Less than 1 year	Less than 0.5 years	Less than 1 year
19	Provide ICT support	Secondary	Organization	All	Min. 250	Less than 1 year	Less than 0.5 years	1-3 years
20	Train monotasking	Secondary	Individual	All	Min. 10	Less than 1 year	Less than 0.5 years	1-3 years
21	Train technostress coping competencies	Secondary	Individual	All	Min. 10	Less than 1 year	Less than 0.5 years	Less than 1 year
22	Offer platforms to exchange experience on ICT use	Secondary	Individual	All	Min. 50	Less than 1 year	0.5-1 year	1-3 years
23	Provide ICT training	Secondary	Individual	All	Min. 10	1-3 years	0.5-1 year	1-3 years
24	Foster sensitization and self-reflection regarding technostress	Secondary	Individual	All	Min. 10	Less than 1 year	0.5-1 year	Less than 1 year

Table 37: Characterization of Technostress Prevention Measures

Appendix C.5 Relevance of Primary Technostress Prevention Measures

Appendix C.5 provides detailed results on the relevance of primary prevention measures to reduce technostressors. PM stands for the respective prevention measure number as indicated in Table 10 in Subchapter 4.1.4.

PM	**Complexity**	**Insecurity**	**Interruptions**	**Invasion**	**Invasion of Privacy**	**Overload**	**Role Ambiguity**	**Uncertainty**	**Unreliability**	**∑ Stressors**
1	6,00 (11x)						5,92 (13x)		5,08 (13x)	**3**
2			4,85 (13x)						4,00 (11x)	**2**
3	5,00 (10x)									**1**
4	6,00 (13x)				5,00 (11x)		5,92 (13x)		6,00 (13x)	**4**
5								5,58 (12x)		**1**
6		4,92 (13x)		5,00 (13x)	5,09 (11x)					**3**
7										**0**
8					5,23 (13x)					**1**
9					5,15 (13x)					**1**
10	4,92 (12x)									**1**
11			5,08 (13x)	5,83 (12x)	5,00 (12x)					**3**
12			6,00 (13x)	6,00 (13x)		4,83 (12x)				**3**
13		6,00 (12x)		5,85 (13x)	5,00 (11x)			4,92 (13x)		**4**
14										**0**
15	5,92 (13x)	5,92 (13x)								**2**
16		6,00 (12x)					5,08 (12x)	5,15 (13x)		**3**
17			5,00 (13x)	5,92 (12x)		5,17 (12x)				**3**
∑PM	**5**	**4**	**4**	**5**	**6**	**2**	**3**	**3**	**3**	

Table 38: Relevance of Primary Technostress Prevention Measures

Appendix D Assessing the Use of Digital Innovation for Sustainable Customer Behavior

Appendix D.1 Pre-study Questionnaire

In the following, the original questionnaire on to-go reusable systems presented to respondents in the pre-study phase is detailed. Please note that the questions are translated to English by the authors, as the initial questions were posed in German.

1:

Dear Participants,

Thank you very much for your willingness to participate in my survey. As part of my master's thesis, I am conducting this survey on the usage of to-go reusable systems.

Below are some important notes regarding your participation in the survey:

- Answering the following questions will take about 5-7 minutes.
- You may also participate if you have not yet used to-go reusable systems.
- Please answer the questions and statements to the best of your knowledge and belief; there are no right or wrong answers.
- Please fill out the questionnaire completely and carefully so that your answers can be considered in the evaluation.
- Please do not use the "Back" button on your browser, as this may interrupt the survey.

Data Protection:

Your participation is voluntary and anonymous. According to the General Data Protection Regulation (GDPR), the data you provide will be used exclusively for research purposes and will not be shared with third parties. The evaluation of the data will be conducted anonymously and confidentially. It will not be possible to trace back to individual persons.

Declaration of Consent:

By clicking "Next," you confirm that you have read and understood all the information provided. You agree to participate in this study and consent to the analysis of the data collected.

If you have any questions or suggestions regarding this survey, please feel free to contact me.

Thank you again for your participation and have fun!

2:

In Germany, there are some regional and nationwide providers of to-go reusable systems that provide reusable containers for to-go food and beverages. In cooperation with food service providers, various restaurants and cafés offer these systems. Participating food service providers then give customers the reusable alternative for take-away food or beverages.

In this survey, the following to-go reusable system is considered: Customers order their food or beverage as a to-go option in a reusable container that is provided in exchange for a deposit as part of the payment process. For a reusable cup, the deposit is usually around 1€, for a reusable plate around 5€. The customer consumes the food or beverage as usual and can then return the container to the provider in exchange for the deposit. The deposit is refunded upon return. The reusable containers are cleaned and then reintroduced into the cycle.

3:

Have you ever used to-go reusable systems for take-away food or beverages in the past? *(For example, ReCup/Rebowl, ReCIRCLE, Vytal, Relevo, etc.)*

- Yes
- No
- I don't know

3.1. Filter Question, if the answer to the previous question was = Yes

How often do you use to-go reusable systems?

- Every day
- Almost every day
- About half the days
- Occasionally
- Rarely
- Never

Please estimate how often you used to-go reusable systems in the past month.

- Every day
- Almost every day
- About half the days
- Occasionally
- Rarely
- Never

Please estimate the proportion of your to-go consumption where you use to-go reusable systems.

(Example: For every second to-go purchase, I use a reusable system. Proportion = 50%)

4:

What prevents you from using to-go reusable systems (more often)? *(Multiple answers possible)*

- Lack of quality of the containers
- Sanitary concerns
- No interest in using to-go reusable systems
- No demand
- None of the mentioned reasons
- Other (please specify):

5:

Please evaluate the following statements on a 7-point scale.

In general, I find using to-go reusable systems: *(When answering on mobile devices: Please evaluate the opposite adjectives above and below the scale.)*

- very bad | very good

- very harmful | very beneficial
- very stupid | very smart
- very unpleasant | very pleasant
- very undesirable | very desirable
- very negative | very positive

When I use to-go reusable systems, the people who are important to me:

- don't welcome it at all | fully welcome it
- don't appreciate it at all | fully appreciate it
- don't find it desirable at all | find it very desirable
- don't support it at all | fully support it

Please evaluate the following statements.

Most of the people that are important to me, use to-go reusable systems.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

The people in my life whose opinions I value use to-go reusable systems.

- Strongly disagree
- Disagree
- Rather disagree

- Neutral
- Rather agree
- Agree
- Strongly agree

6:

How much control do you have over your usage behavior regarding to-go reusable systems?

- Absolutely no control
- Almost no control
- Little control
- Neutral
- Some control
- A lot of control
- Full control

Using to-go reusable systems for me is:

- Absolutely not possible
- Not possible
- Rather not possible
- Neutral
- Rather possible
- Possible
- Very possible

If I wanted to, it would be easy for me to use to-go reusable systems.

- Very unlikely

- Unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Likely
- Very likely

It makes no sense to do your best for the environment, if others do not do the same.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

7:

Please evaluate the following statements.

I find that there are many opportunities to use to-go reusable systems in my environment.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

I find that using to-go reusable systems in my environment is easy.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

I find it convenient to use to-go reusable systems in my environment.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

Please evaluate the following statements.

I will use to-go reusable systems in the future.

- Very unlikely
- Unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Likely

- Very likely

I will consider using to-go reusable systems in the future.

- Very unlikely
- Unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Likely
- Very likely

I will try to use to-go reusable systems in the future.

- Very unlikely
- Unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Likely
- Very likely

I intend to use to-go reusable systems in the future.

- Very unlikely
- Unlikely
- Somewhat unlikely
- Neutral
- Somewhat likely
- Likely
- Very likely

8:

Please evaluate the following statements.

It is important to me to prevent environmental pollution.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

It is important to me to protect the environment.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

This is a control question: Please select "Agree" at this point to confirm your attention.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree

- Agree
- Strongly agree

It is important to me to respect nature.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

It is important to me that nature is in harmony with people.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

Please evaluate the following statements.

I like to test and use new technologies.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral

- Rather agree
- Agree
- Strongly agree

I am interested in new technologies and follow corresponding news.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

I see myself as open to new technologies.

- Strongly disagree
- Disagree
- Rather disagree
- Neutral
- Rather agree
- Agree
- Strongly agree

9:

How old are you?

- 17 or younger
- 18-20
- 21-29

- 30-39
- 40-49
- 50-59
- 60 or older

What gender do you identify as?

- Female
- Male
- Diverse

10:

What is your highest educational degree?

- No degree
- Secondary modern school qualification (German Hauptschulabschluss)
- High-school diploma
- German Abitur
- Completed vocational training
- University degree (Bachelor, Master, other)

What is your current professional status?

- Employed
- Unemployed
- Unable to work
- Public official
- Pensioner
- Self-employed
- Student

- Other (please specify):

How did you hear about this survey?

- Social media
- Friends
- SurveySwap
- E-Mail
- Other

11:

Thank you for your participation! The survey is now completed, and you can close this page.

Appendix D.2 List of To-go Reusable Systems Companies

Appendix D.2 lists the business focus of all TGRS companies used for analyzing applications of digital innovation to improve customer behavior.

#	**Business focus**
1	Dish supplier; TGRS consulting
2	Dish supplier
3	Dish supplier; TGRS operator
4	Dish supplier; TGRS operator
5	Dish supplier; TGRS operator
6	Dish supplier; TGRS operator
7	Dish supplier
8	TGRS operator
9	Dish supplier; TGRS operator
10	Dish supplier; TGRS operator
11	TGRS operator
12	Dish supplier; TGRS operator
13	Dish and vending machine supplier
14	Dish supplier; TGRS operator
15	Dish supplier; TGRS operator
16	Dish supplier; TGRS operator
17	Dish supplier; TGRS operator
18	Dish supplier; TGRS operator
19	Dish supplier; TGRS operator
20	Dish supplier; TGRS operator
21	Dish supplier; TGRS operator

Table 39: List of To-go Reusable Systems Companies Analyzed in the Market Analysis

Appendix E Outcomes of Digital Innovation for Sustainability

Appendix E.1 Steps Involved in Smart Urban Agriculture Taxonomy Design and Evaluation Process Based on Kundisch et al. (2022).

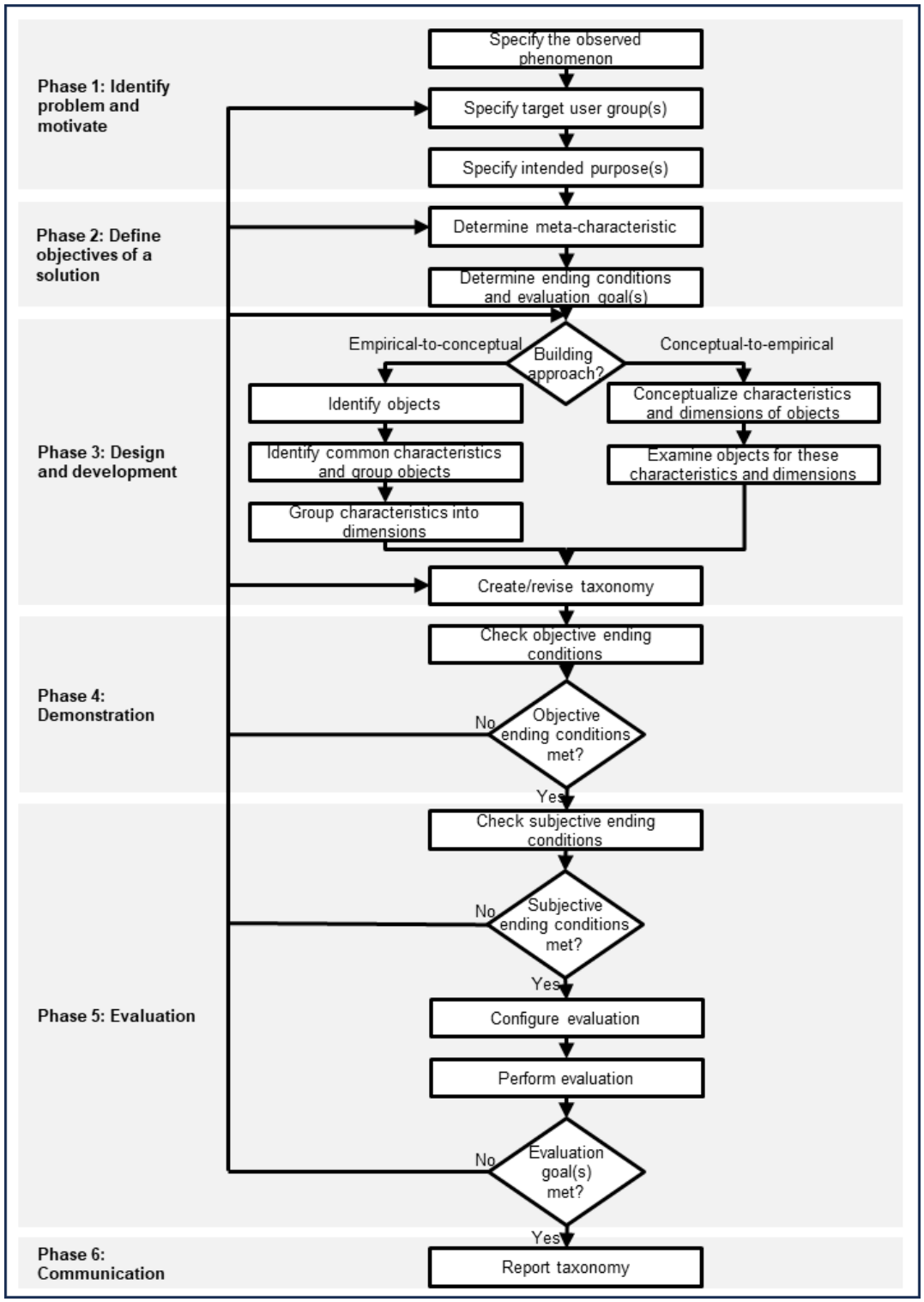

Figure 31: Steps Involved in Smart Urban Agriculture Taxonomy Design and Evaluation Process

Appendix E.2 Search Protocol for Smart Urban Agriculture

Appendix E.2 presents the search protocol followed for deriving smart urban agriculture taxonomy dimensions and characteristics.

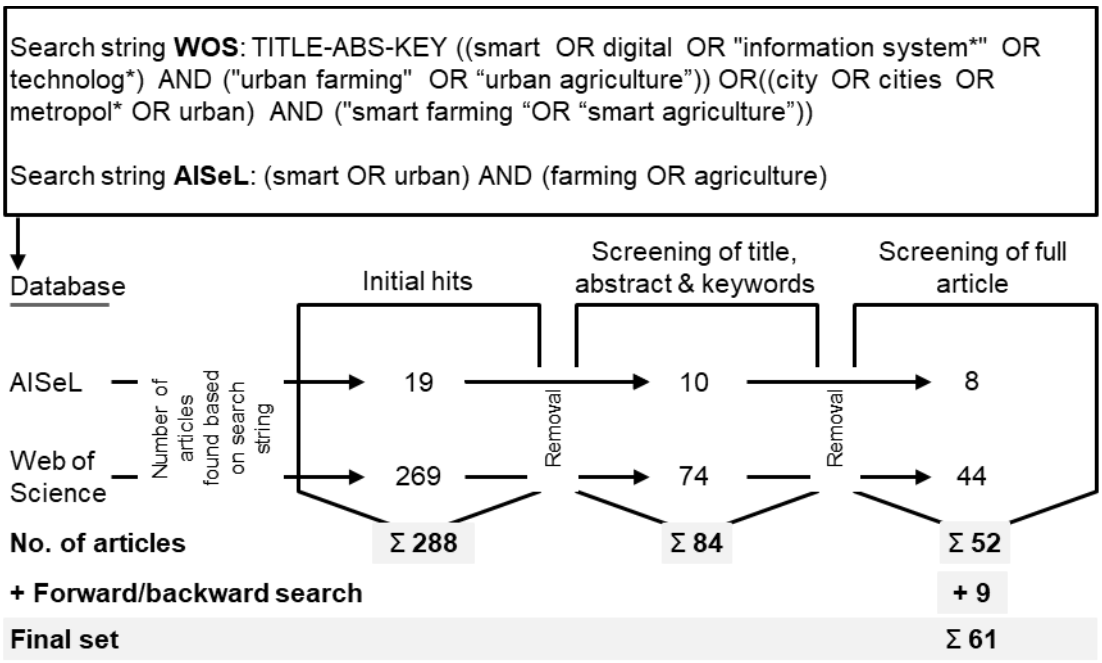

Figure 32: Search Protocol for Smart Urban Agriculture

Appendix E.3 Smart Urban Agriculture Search Results

Appendix E.3 lists all studies included in the taxonomy development process as a result of the literature review presented in Appendix E.2.

Study	**Urban Agriculture Context**
Al-Ali et al. (2020)	Digital twins for urban agriculture simulation
Ampatzidis et al. (2017)	Robotic plant management
Appeaning Addo (2010)	Remote sensing of urban farmland
Asciuto et al. (2019)	Urban aquaponic systems
Ayaz et al. (2019)	IoT-based agriculture
Basterrechea et al. (2021)	Sensor-based irrigation management
Bento et al. (2019)	Agriculture 4.0
Bojja and Ambati (2020)	Social media-based plant disease management
Broad et al. (2021)	Acceptance of high-tech controlled agriculture
Büyüközkan et al. (2021)	Vertical farming technology assessment
C. L. Chang et al. (2019)	Intelligent lighting in urban rooftop farms
Cıceklı and Barlas (2014)	High-tech vertical farming technology
Diehl et al. (2020)	Urban agriculture planning
Egerer et al. (2020)	Spatial data-based urban agriculture planning
Espelt (2020)	Digital platforms for community agriculture
Farhangi et al. (2020)	High-tech urban agriculture
Félix et al. (2018)	Urban vertical gardens
Ghandar et al. (2021)	Digital twins for urban agriculture planning
Glaros et al. (2021)	Urban food security
Gravalos et al. (2019)	Robotic irrigation management
Hamidon et al. (2020)	Smart vertical garden systems
Harada et al. (2018)	Urban rooftop agriculture
Harun et al. (2019)	IoT-based growth monitoring

Study	Urban Agriculture Context
Hugo et al. (2021)	Rooftop greenhouse design
Joo and Jeong (2017)	IT-based plant factories
Khan and Ahmed (2017)	Simulations for vertical farming
Kosorić et al. (2019)	Acceptance of productive facades
Kwak et al. (2017)	Nano sensor-based plant monitoring
Lange et al. (2017)	Agent-based modelling for urban agriculture
Lüttenberg et al. (2018)	Predictive maintenance in smart urban agriculture
Mohareb et al. (2017)	Urban agriculture-based energy reduction
Moon et al. (2009)	Digitalization differences of rural and urban areas
Nadal et al. (2017)	Urban agriculture assessment
Niemöller et al. (2019)	Smart glasses for service support
Niemöller et al. (2017)	Smart glasses for service support
Ofori and El-Gayar (2021)	IT-based weed detection
Parada et al. (2017)	IoT in urban planning
Podder et al. (2021)	IoT in urban agriculture monitoring
Popli et al. (2021)	IoT in urban farming
Rogers and Hiner (2016)	Urban agriculture planning
Rut and Davies (2018)	Sustainable food transitions
Saha and Eckelman (2017)	Urban agriculture assessment
Sakthi and Kiruthika (2019)	Hydroponic-based vertical farming
Sanyé-Mengual et al. (2017)	Urban rooftop agriculture
Senapati and Behera (2020)	Vertical farming
Senes et al. (2016)	Urban community gardens
Shamshiri et al. (2018)	Greenhouse automation in urban agriculture
S. Singh and Tayal (2021)	Urban food management
Sioen et al. (2018)	Urban land use for resilience

Study	Urban Agriculture Context
Skarbit et al. (2017)	Urban agriculture monitoring
Strobel (2020)	IoT in smart agriculture
Surantha and Surantha (2020)	IoT-based smart hydroculture
Tablada et al. (2018)	Urban productive facades
W. K. Tan et al. (2020)	LED lighting in urban agriculture
Tavan et al. (2021)	Smart irrigation in vertical farming
Taylor et al. (2021)	IT-enabled green city planning
Tolga and Basar (2020)	Urban farming assessment
E. Wang et al. (2018)	IoT in smart irrigation
R. Winkler (2021)	Urban agriculture monitoring
Zambrano-Prado et al. (2021)	Urban rooftop agriculture
Q. Zhang et al. (2013)	Sensors in smart cities

Table 40: Search Results of the Literature Review on Smart Urban Agriculture

Appendix E.4 Exemplary Coding Scheme

Appendix E.4 shows exemplary coding schemes for one study in the taxonomy development process (Table 41) as well as for one interview in the development of readiness factors (Table 42).

<table>
<tr><th></th><th>Step 1: Open coding</th><th>Step 2a:
Axial coding</th><th>Step 2b:
Axial coding</th><th>Step 3:
Selective coding</th></tr>
<tr><td>Description of coding steps</td><td>Highlighting information on SUA technologies' characteristics</td><td>Grouping characteristics into dimensions</td><td>Assigning dimensions to building blocks describing digital technology, data, and urban agriculture approach</td><td>Reducing and redefining the characteristics in each dimension</td></tr>
<tr><td rowspan="3">Exemplary literature: Dorr et al. (2021)</td><td rowspan="3">• Ground indoor hydro
• Ground indoor soil
• Ground open air hydro
• Ground open air soil
• Rooftop open air hydro
• Rooftop open air soil
• Indoor heated
• Indoor not heated</td><td colspan="3">Digital Technology building block
None</td></tr>
<tr><td colspan="3">Data building block
None</td></tr>
<tr><td>Type of Urban Agriculture
Ground indoor
Ground open air
Rooftop open air
Nutrient Medium
Hydro
Soil
Heating Support
Indoor heated
Indoor not heated</td><td>Approach building block

Type of Urban Agriculture
Ground indoor
Ground open air
Rooftop open air
Nutrient Medium
Hydro
Soil
Heating Support
Indoor heated
Indoor not heated</td><td>Approach building block

Type of Urban Agriculture
Ground indoor
Ground open air
Rooftop open air
Nutrient Medium
Water (renamed)
Soil
Heating Support
(dropped)</td></tr>
</table>

Table 41: Exemplary Coding Scheme 1 – Taxonomy

	Step 1: Open coding	**Step 2a: Axial coding**	**Step 2b: Axial coding**	**Step 3: Selective coding**
Description of coding steps	Highlighting information on factors that contribute to or prevent SUA organizations from using digital technologies in urban agriculture	Grouping information into categories aligned with Lokuge et al.'s (2019) categories	Paraphrasing and building readiness factors in each readiness category	Redefining each readiness factor
Exemplary interview: ID01	*But in the city it's easier because you are getting connected to everything in the city. You can use services that are in the city to implement stuff better.*	**Resource Readiness**	**Resource Readiness** Technological environment	**Resource Readiness Factor** IT Infrastructure
	I think, especially the differentiation between the new type of farmer with a high IT-affinity. That point is very important for the future planning to make sure that farmers of the future really bring with them skills and that type of knowledge.	**Resource Readiness**	**Resource Readiness** Missing expertise	**Cognitive Readiness Factor** IT Expertise
	Not that much but of course other countries like developing countries are suffering more. […] So it's really hard in that case to rely on technologies that come from abroad, but in Israel it's bit more simple to do it.	**Partnership Readiness**	**Partnership Readiness** Difficulties to build partnerships in developing countries (dropped due to no other mentioning in any other interview)	
	Technologies are really similar today! Building a Volkswagen factory looks like building a factory that grows tomatoes, so it pretty much looks the same: very machinery, very automatically, everything related to climate control and stuff like that is really similar to other companies.	**Innovation Valence**	**Innovation Valence** Using IT/innovations from other industries (dropped due to no other mentioning in any other interview)	
	This industry is really in the beginning of a long journey. It'll take a long time until we	**Strategic Readiness**	**Strategic Readiness** Industry is a niche: The entire	**Strategic Readiness Factor**

	Step 1: Open coding	Step 2a: Axial coding	Step 2b: Axial coding	Step 3: Selective coding
	will have come up with economic benefits. […]. They will prefer to invest in other stuff.		ecosystem must be aware of the financial and sustainability-related benefits of SUA to foster trust and willingness to invest.	Stakeholder awareness
	It's really hard for farmers to start doing it when there is no regulation that actually helps them to do it or even push them to do it.	**Regulatory Readiness**	**Regulatory Readiness** Regulations are too old/don't exist: To enable benefits for smart cities, policymakers must adapt existing regulations – established with reference to traditional farming – to the new requirements of urban agriculture.	**Regulatory Readiness Factor** Laws

Table 42: Exemplary Coding Scheme 2 - Readiness Factors

Appendix E.5 List of Smart Urban Agriculture Interviewees

Appendix E.5 lists all interview partners as part of the taxonomy and readiness factor development and evaluation process.

ID	Role of Expert	Current Position in Organization	Organization	Country of Residence	Sex	Length of interview
01	Taxonomy expert	Post-doctoral IS researcher	Research institute	Germany	Male	21 min
02	Taxonomy expert	Senior doctoral candidate in IS	Research institute	Germany	Female	20 min
03	Taxonomy expert	Post-doctoral IS researcher	Research institute	Germany	Female	26 min
04	Taxonomy expert	Post-doctoral IS researcher	Research institute	Germany	Female	16 min
05	Taxonomy expert	Professor in IS	Research institute	Germany	Male	20 min
06	Green IS expert	Professor in IS	Research institute	Germany	Male	18 min
07	Green IS expert	Post-doctoral IS researcher	Research institute	Germany	Male	23 min
08	Green IS expert	Post-doctoral IS researcher	Research institute	Germany	Male	27 min
09	Green IS expert	Post-doctoral IS researcher	Research institute	Germany	Male	11 min
10	Practitioner	Consultant	Startup for urban agriculture	Israel	Male	57 min
11	Practitioner	Project manager	Public institution urban agriculture	Germany	Male	29 min
12	Practitioner	Head of hydroculture	Startup urban agriculture	Germany	Female	30 min
13	Practitioner	Project coordinator Indoor Farming	Public institution urban agriculture	Germany	Male	45 min
14	Practitioner	CEO	Startup urban agriculture	Germany	Male	38 min

ID	Role of Expert	Current Position in Organization	Organization	Country of Residence	Sex	Length of interview
15	Practitioner	Co-Founder	Startup urban agriculture	Germany	Male	35 min
16	Practitioner	Head of Marketing	Startup urban agriculture	Germany	Male	47 min
17	Practitioner	Co-Founder	Startup urban agriculture	Germany	Female	29 min
18	Practitioner	CEO	Urban farm	Austria	Female	45 min
19	Practitioner	Developer in digitization and automation	Tech-company	Germany	Male	49 min
20	Practitioner	Farmer	Urban Farm	Germany	Male	30 min
21	Practitioner	Farmer	Urban Farm	Germany	Male	22 min
22	Practitioner	Marketing manager	Urban Farm	Germany	Female	25 min
23	Practitioner	CEO	Landscape Planning Company	Netherlands	Male	30 min
24	Practitioner	Architect and urban planner	City administration	Germany	Male	25 min
25	Practitioner	Project coordinator Department for Environmental Protection	City administration	Germany	Male	42 min

Table 43: List of Interviewees on Smart Urban Agriculture

Appendix E.6 Real-life Examples for Smart Urban Agriculture

Appendix E.6 presents the sets of real-life SUA examples used for evaluating the taxonomy in iterations 1-4 (Table 44) and iteration 5 (Table 45).

ID	Technology Description	Source
01	Plant factory with artificial light and auto-dosing technology for the production of terrestrial plants	Startup CityFarm[10]
02	Open-source monitoring system of environmental and soil data within aquaponics	Startup Aquapioneers[11]
03	IoT-based automatic farming system for salad and herbs	Startup infarm Berlin[12]
04	Connected, mutually communicating, and standardized units for the production of fish, insects, and plants	Research project Cubes Circle[13]
05	Automated growth tray system for crops	Tech company IGS[14]
06	Smart hydroculture control system based on IoT and fuzzy logic	Literature (Surantha & Surantha, 2020)
07	Growth analysis system for IT-based plant factory	Literature (Joo & Jeong, 2017)
08	Airborne sensors for assessing rooftop greenhouses' potential	Literature (Nadal et al., 2017)
09	Automatic and intelligent light and water system for plant production on facades	Literature (Kosorić et al., 2019)
10	Decision support system for aquaponics based on Digital Twins	Literature (Ghandar et al., 2021)

Table 44: Real-life Example Sample for Taxonomy Development Iterations 1-4

[10] https://cityfarm.my/products/custom-setup
[11] http://aquapioneers.io/
[12] https://www.infarm.com/news/infarm-heralds-the-next-generation-of-cloud-enabled-farming/
[13] https://www.cubescircle.de/en/home/project
[14] https://www.intelligentgrowth.io/technology/growth-towers

ID	Technology Description	Source
01	pH water tester for monitoring water quality in hydroponic systems	CityFarm[15]
02	GroLine monitor for monitoring nutrient levels in hydroponic systems	CityFarm[16]
03	Automatic nutrient dosing system for hydroponic systems	CityFarm[17]
04	Plant factory with artificial light and auto-dosing technology for the production of terrestrial plants	CityFarm[18]
05	Open-source monitoring system of environmental and soil data within aquaponics	Aquapioneers[19]
06	Automated, high-capacity, indoor growing center	infarm[20]
07	Cloud-connected indoor vertical farm	infarm[21]
08	Automated, indoor GrowthTowers with vertical farming elements	IGS[22]
09	Medium-sized hydroponic vertical indoor farm	Artechno Growsystems[23]
10	Small-sized hydroponic vertical indoor farm for research and innovation	Artechno Growsystems[24]
11	Deep float hydroponic system	Artechno Growsystems[25]
12	Automated harvesting system for hydroponic systems	Artechno Growsystems[26]
13	Automated urban vertical hydroponic systems	Kalera[27]
14	Automated harvesting robot for urban indoor farms	Organifarms[28]
15	Aquaponic farming system	ECF[29]

[15] https://cityfarm.my/products/hanna-instruments-waterproof-pocket-ph-tester-with-0-1-resolution-phep-hi98107
[16] https://cityfarm.my/products/groline-monitor-for-hydroponic-nutrients
[17] https://cityfarm.my/products/hanna-instruments-groline-nutrient-dosing-system-auto-doser-hi-hi981413-00
[18] https://cityfarm.my/products/custom-setup
[19] http://aquapioneers.io/aquaponics-kit/
[20] https://www.infarm.com/infarm-heralds-the-next-generation-of-cloud-enabled-farming/
[21] https://www.infarm.com/infarm-to-open-one-of-the-largest-vertical-farming-facilities-in-europe/
[22] https://www.intelligentgrowthsolutions.com/product/growth-towers
[23] https://artechno.nl/en/vertical-farming/avf-compact
[24] https://artechno.nl/en/vertical-farming/avf-junior
[25] https://artechno.nl/en/hydroponics
[26] https://artechno.nl/en/processing-systems
[27] https://kalera.com/who-we-are/
[28] https://www.organifarms.de/product
[29] https://www.ecf-farmsystems.com/aquaponik

ID	Technology Description	Source
16	Indoor hydroponic container farming system	Vertical Roots[30]
17	Small-scale vertical farming plant cube for private households	agrilution[31]
18	Advanced hydroponic indoor garden	Vegger[32]
19	Robotic vertical indoor farm	AMS[33]
20	Support app for private gardening	Plantura[34]
21	Support app for community garden management	Community GardenApp[35]
22	Smart indoor gardening system	Bosch[36]
23	Monitoring system for green roofs	Nexsens[37]
24	Vertical aeroponic farm	Altius Urban Farms[38]
25	Vertical aeroponic farming technology	Tower Farms[39]
26	Smart vertical farm	Square Roots[40]
27	Support app for private urban gardening	Urban Gardener[41]
28	Small-scale urban aquaponic systems	Go Green Aquaponics[42]
29	Small-scale automated green house for private households	neoFarms[43]
30	Technology-supported vertical urban farm	Vertical Field[44]
31	Technology-supported vertical urban farm	Rooftop Republic[45]
32	Outdoor aeroponic gardening system	Aerospring hydroponics[46]

Table 45: Real-life Example Sample for Taxonomy Development Iteration 5

[30] https://www.verticalroots.com/how-we-farm-indoor-container/
[31] https://de.agrilution.com/plantcube
[32] https://www.vegger.nl/products/?lang=en
[33] https://www.ams-institute.org/urban-challenges/metropolitan-food-systems/growx-20-robotic-vertical-farm/
[34] https://www.plantura.garden/app/
[35] https://www.communitygardenapp.com/
[36] https://www.bosch-home.com/de/shop/smart-indoorgardening
[37] https://www.nexsens.com/case_studies/green_roof_monitoring.htm
[38] https://altiusfarms.com/
[39] https://www.towerfarms.com/us/en/advantages
[40] https://squarerootsgrow.com/
[41] https://urbangardener.io/
[42] https://gogreenaquaponics.com/collections/home-systems/products/aquaurban-60-gallon-aquaponic-system
[43] https://www.neofarms.com/benefits-de
[44] https://www.verticalfield.com/vertical-farming/
[45] https://rooftoprepublic.com/
[46] https://aerospringhydroponics.com/pages/aerospring-outdoor

Appendix E.7 Matching of Real-life Example Sample to Taxonomy

Appendix E.7 provides the matching of all real-life examples to the taxonomy dimensions and characteristics.

Part 1: Examples #1-11:

Dimension	**Characteristic**	**Example (refers to Table 45)**										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Role	Enabler				x		x	x	x	x	x	x
	Supporter	x	x	x		x						
Functionality Level	Monitoring	x	x									
	Recommendations											
	Adaption			x	x	x	x	x	x	x	x	x
Support in UA Planning	Yes						x	x	x	x	x	
	No	x	x	x	x	x						x
Interface	Solution-Integrated					x						x
	External Devices	x	x	x	x		x	x	x	x	x	
Source	Aerial Remote Sensing											
	Ground-based Sensing	x	x	x	x	x	x	x	x	x	x	x
	Agent-related Sensing											
Content	Process Data											
	Environment Data	x	x			x						
	Product and Environment Data			x	x		x	x	x	x	x	x
Type	Ground Indoor	x	x	x		x						x
	Ground Open Air											
	Vertical Indoor				x		x	x	x	x	x	
	Vertical Open Air											
	Rooftop Open Air											
End Product	Animals and Plants					x						
	Plants	x	x	x	x		x	x	x	x	x	x
Nutrient Medium	Soil						x	x				
	Water	x	x	x	x	x				x	x	x
	Air								x			

Part 2: Examples #12-22:

Dimension	Characteristic	Example (refers to Table 45)										
		12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Role	Enabler	x	x	x			x	x	x			x
	Supporter				x	x				x	x	
Functionality Level	Monitoring											
	Recommendations									x	x	
	Adaption	x	x	x	x	x	x	x	x			x
Support in UA Planning	Yes						x				x	
	No	x	x	x	x	x		x	x	x		x
Interface	Solution-Integrated	x										x
	External Devices		x	x	x	x	x	x	x	x	x	
Source	Aerial Remote Sensing											
	Ground-based Sensing	x	x	x	x	x	x	x	x			x
	Agent-related Sensing									x	x	
Content	Process Data	x		x						x	x	
	Environment Data											
	Product and Environment Data		x		x	x	x	x	x			x
Type	Ground Indoor	x			x	x						x
	Ground Open Air									x	x	
	Vertical Indoor		x	x			x	x	x			
	Vertical Open Air											
	Rooftop Open Air											
End Product	Animals and Plants				x							
	Plants	x	x	x		x	x	x	x	x	x	x
Nutrient Medium	Soil			x			x		x	x	x	
	Water	x	x		x	x		x				x
	Air											

Part 3: Examples #23-32:

Dimension	Characteristic	Example (refers to Table 45)									
		23	24	25	26	27	28	29	30	31	32
Role	Enabler							x			
	Supporter	x	x	x	x	x	x		x	x	x
Functionality Level	Monitoring	x					x				
	Recommendations					x					
	Adaption		x	x	x			x	x	x	x
Support in UA Planning	Yes									x	
	No	x	x	x	x	x	x	x	x		x
Interface	Solution-Integrated		x	x			x	x		x	x
	External Devices	x			x	x			x		
Source	Aerial Remote Sensing									x	
	Ground-based Sensing	x	x	x	x		x	x	x		x
	Agent-related Sensing					x					
Content	Process Data					x					
	Environment Data	x					x			x	
	Product and Environment Data		x	x	x			x	x		x
Type	Ground Indoor										
	Ground Open Air					x	x				x
	Vertical Indoor			x	x			x			
	Vertical Open Air								x		
	Rooftop Open Air	x	x							x	
End Product	Animals and Plants						x				
	Plants	x	x	x	x	x		x	x	x	x
Nutrient Medium	Soil	x			x	x			x	x	
	Water						x				
	Air		x	x				x			x

Table 46: Matching of Real-life Example Sample to Taxonomy

Appendix E.8 Interview Guide for Smart Urban Agriculture

Appendix E.8 presents an extract of the semi-structured interview guide for smart urban agriculture.

Category	Questions
	General Section
Introduction	• Short introduction on researchers' background and research project • Clarification on data processing (possibility of recording, anonymization of data and further processing of interview content)
Interviewee's background	• Can you briefly tell us about your professional/research background? • What is your current position?
	Specific Section (Researchers)
Taxonomy Evaluation	• *[Showing taxonomy] As part of our research, we looked at numerous digital technologies that are/can be used in urban agriculture to make cities more resilient and improve their self-sufficiency. In the following, we would like to evaluate this taxonomy with you.* • Do you see major flaws in this taxonomy? • Do you miss any dimensions or characteristics? • How do you rate our dimensions and characteristics with regard to its conciseness, robustness, comprehensibility, extendibility, and degree of explanation?
	Specific Section (Practitioners)
General Questions on IT-usage	• Do you consider digitization to be relevant in your industry? • Do you already use digital technologies in your company?
Readiness Factors	• *We would like to use the interview to talk about your willingness to adopt digital technologies in urban agriculture.* • What factors could contribute/prevent you from using digital technologies in urban agriculture? (upon request: categories such as resources, culture, strategy, cognitive, partnership, innovation) • What was the initial trigger for you to start implementing digital technologies? • What are you doing now specifically to implement digital technologies?

Table 47: Interview Guide for Smart Urban Agriculture

Appendix F Research Agenda for Digital Social Innovation

Appendix F.1 Digital Social Innovation Literature Coding Results

Appendix F.1 provides an overview of the 135 studies found through our systematic literature review. Each study is presented with its classification to at least one characteristic of each of the three digital social innovation dimensions, i.e., digital technology, digital innovation, and social innovation. Each dot represents the main classification (i.e., 1st order) of a study in our sample. If a study peripherally touched upon a second characteristic of a dimension (for example, the focus of the contribution is on DSI outcome, but a small part of the study also refers to DSI environments), we plotted an "x" (i.e., 2nd order). Accordingly, the dots show characteristics that were central to the studies, and the "x" show characteristics that were rather peripherally addressed.

Study	**Digital Technology Dimension**		**Digital Innovation Dimension**			**Social Innovation Dimension**		
	Characteristics							
	Digital technologies as a means	*Digital technologies as an end*	*Actions*	*Outcome*	*Environment*	*Profit*	*Planet*	*People*
Abejirinde et al., 2018		•	x	•				•
Abraham & Dao, 2017	•			•		•	x	x
Abraham & Dao, 2019	x	•		•		x	•	x
Abraham & Mohan, 2015	x	•		•		x	•	x
Adaba & Ayoung, 2017		•			•	•		
Agasisti et al., 2020		•	x	•				•
Ahuja & Chan, 2014	•				•	•	x	x
Ahuja & Chan, 2016		•			•	•	x	x
Ahuja & Chan, 2020	•	x		•		•	x	x
Aitken et al., 2021		•	•					•
Alaboudi et al., 2016		•	•	x	x			•
Amenta et al., 2021		•			•		•	
Andrade-Rojas & Lin, 2019		•			•		•	
Antonioli et al., 2018	•		•				•	
Arena et al., 2018		•			•	x	x	•
Arts et al., 2015	•	x	•				•	
Arts et al., 2016	•	x			•		•	
Arts et al., 2020		•		•	x		•	
Barberan-Garcia et al., 2021		•		•				•
Bengtsson & Ågerfalk, 2011	x	•			•	x	•	x
P. Bhatt et al., 2016	x	•	•			x		•

Study	Digital Technology Dimension		Digital Innovation Dimension			Social Innovation Dimension		
	Characteristics							
	Digital technologies as a means	*Digital technologies as an end*	*Actions*	*Outcome*	*Environment*	*Profit*	*Planet*	*People*
Bloom et al., 2017		•			•			•
Bonina, Koskinen, et al., 2021	•	x		•	x	x	x	•
Bonina, López-Berzosa, & Scarlata, 2021		•		•		x	x	•
Broadbent & Cara, 2018		•		•			•	
Buck et al., 2020		•		•		x	x	•
Butler & Hackney, 2015		•	•		x		•	
Buttol et al., 2012	•		•				•	
Carberry et al., 2019		•			•		•	
Cecere et al., 2014		•	•	x	x		•	
Chatfield et al., 2019		•			•	x	x	•
Cioffi et al., 2020		•		•			•	
Ciruela-Lorenzo et al., 2020		•	•			x	x	•
Cosimato & Vona, 2021		•		•		x	•	x
Csedő et al., 2021	•		•		x		•	
Cvar et al., 2020		•		•		x	•	x
Daum et al., 2021		•		•		•		
Dong & Götz, 2021	x	•			•			•
Dreyer et al., 2017		•	•			x	x	•
El-Kassar & Singh, 2019	•				•		•	
Emilsson et al., 2020		•	•					•
Essén & Conrick, 2008		•	•					•
Falk & Ryan, 2007		•		•			•	
Foster & Heeks, 2013		•	x			x		•
Fuger et al., 2017	•		x		•			•
Furstenau et al., 2016		•	•					•
Galán-Díaz et al., 2015		•	x		•		•	
Garske et al., 2021		•		•	x		•	
Gavrilović & Maksimović, 2018		•	•			x	•	x
Gebken et al., 2021		•	x		•			•
Ghazal et al., 2021		•		•				•
George et al., 2021		•		•	x		•	
de Georgio Ferrari Trecate et al., 2020		•		•		x	x	•
Gerritsen et al., 2020	x	•	•				•	x
Ghobakhloo et al., 2021	•	x	•			X	•	x
Gogan et al., 2020	•	x	x		•			•
Guyader et al., 2021		•	x		•		•	x
J. Han et al., 2020		•		•			•	
Hanelt et al., 2017		•		•	x		•	
Harvey & Fisher, 2013		•	x		•			•
Hiteva & Foxon, 2021		•		•		x	•	x
Hird et al., 2016	•	x	•					•

Study	Digital Technology Dimension		Digital Innovation Dimension			Social Innovation Dimension		
	Characteristics							
	Digital technologies as a means	*Digital technologies as an end*	*Actions*	*Outcome*	*Environment*	*Profit*	*Planet*	*People*
Hjalmarsson & Lind, 2011		•	•		x	x	•	x
Hosseini et al., 2018		•	•			x	•	x
Howell et al., 2018		•		•		•		
Hsu et al., 2019	•				•	x	x	•
Huh & Kim, 2019	•				•			•
Husar & Ondrejicka, 2019		•		•			•	x
Iuorio et al., 2019	•			•	x	x	x	•
Kapoor et al., 2015		•		•			x	•
Keijzer-Broers & de Reuver, 2016		•	•					•
Kelly & Noonan, 2017	•		•					•
Ketter et al., 2016	•	x	•	x			•	
Koch et al., 2018		•	x		•			•
Kohler & Chesbrough, 2019	•		•			x	x	•
Lajoie-O'Malley et al., 2020		•		•			x	•
Lassar et al., 2021		•		•				•
Maaravi & Heller, 2021	•	x	•			x		•
Madianou, 2019	x	•			•			•
Maffey et al., 2015		•	•				•	
Majchrzak & Shepherd, 2021	•	x	•					•
McCampbell et al., 2018	•		x	•		x		•
McLoughlin et al., 2019		•		•				•
Mehmood & Imran, 2021	•		•			x	x	•
Melville, 2010		•	x	•	x	x	•	
Mettler et al., 2017		•	•					•
Michard et al., 2017		•		•				•
Misuraca & Pasi, 2019		•	x	•		•		
Moss et al., 2020		•		•				•
Munthali et al., 2018	•		x		•	•		
Nasiri et al., 2022		•			•	x	•	x
Nikiforova, 2021	•			•				•
Nittas et al., 2019		•		•				•
Oborn et al., 2021		•	x		•			•
Park et al., 2021		•			•		•	
Parthiban et al., 2020		•	•		x			•
Rachmawati et al., 2021		•		•		x	x	•
Ravishankar, 2021		•		•		x		•
Regan & Wang, 2014		•	•		x			•
Rey-Garcia et al., 2021		•			•	x		•
Richardson-Ngwenya et al., 2019	•		•					•
Robaeyst et al., 2021		•	x		•			•
Rocha & Almeida, 2024		•		•				•

Study	Digital Technology Dimension		Digital Innovation Dimension			Social Innovation Dimension		
	Characteristics							
	Digital technologies as a means	*Digital technologies as an end*	*Actions*	*Outcome*	*Environment*	*Profit*	*Planet*	*People*
Rodrigo & Palacios, 2021		•			•	x	x	•
Rommetveit et al., 2024		•			•		•	
Røpke, 2012		•		•			•	
Sahay & Walsham, 2014		•	x	•				•
Sahay et al., 2018		•	•					•
Sandeep & Ravishankar, 2015	•		•			x		•
Sanders et al., 2021	•	x	•		x	x	•	x
Sasaki, 2018		•			•		•	
D. Schmitt & Muyoya, 2020		•			•	x	x	•
F. Schmitt et al., 2020		•	•		x			•
Senshaw & Twinomurinzi, 2022	•		x		•			•
Shomali & Pinkse, 2016		•	•	x			•	
Soni et al., 2021		•		•		x	x	•
Suseno & Abbott, 2021		•	•					•
Tarafdar et al., 2013		•		•		•		
Tim et al., 2021		•	•			x		•
Vahtera, 2008		•			•			•
van Osch & Avital, 2010		•	•			x	•	x
Vesci et al., 2021		•	•					•
Vrain & Wilson, 2021		•		•			•	
Watanabe et al., 2019		•	•				•	
Wehn & Evers, 2015	•				•		•	
Witteveen et al., 2017		•	•					•
Y. J. Wu et al., 2020		•	•					•
Wunderlich et al., 2013		•			•		•	
Xiao et al., 2013	x	•	•	x		•		
Yang et al., 2016	•				•		•	
Yang et al., 2017	•				•		•	
Yang et al., 2019		•			•		•	
Yang et al., 2020		•		•			•	
Yousaf et al., 2021	•	x	•		x	x	•	x
J. Zhang & Liang, 2012		•			•	x	•	

Table 48: Full List of Digital Social Innovation Studies and Coding of the Digital Social Innovation Dimensions

Further, Table 49 illustrates the different domains of the journals or conferences from which we extracted the studies as well as the number of studies per domain.

Domain	Number of Studies
Business	20
Communication	4
Computer Sciences	4
Development Studies	8
Economics	2
Environmental Sciences	35
Information Systems (journal)	20
Information Systems (conference)	28
Medical Sciences	11
Natural Sciences	1
Public Sector	2

Table 49: Domains of Integrated Journals and Conferences

Appendix F.2 Interview Details for Digital Social Innovation

To refine the initial research agenda, we conducted 10 expert interviews with Information Systems scholars. The research focus of the IS scholars is either DSI directly or one of the intersecting areas such as digital innovation or Green Information Systems. Table 50 presents a description of the 10 IS scholars including their current academic position, research focus as well as years of experience in research.

ID	Current Position	Research Focus	Years of Experience in Research
R1	PhD Candidate	Digital Innovation	6
R2	PhD Candidate	Digital Technologies for Sustainable Business Models	4
R3	PhD Candidate	Digitalization of the Energy Sector	3
R4	PhD Candidate	Machine Learning for Healthcare	3
R5	PhD Candidate	Digital Social Innovation	5
R6	Post-Doc	Digital Opportunities for Sustainability	14
R7	Associate Professor	Digital Technologies for Sustainability	20
R8	Professor	Digital Social Innovation	8
R9	Professor	Sustainable Mobility	10
R10	Professor	Customer Processes and Sustainability	13

Table 50: Information on Interviewed Digital Social Innovation Scholars

The interview protocol (see Table 51) is structured to gather information and insights from the interviewed scholars on various aspects related to DSI. It comprises a series of questions covering the DSI research agenda. The questionnaire is divided into sections to ensure comprehensive coverage of relevant areas. These sections include:

- **General DSI Research Agenda Section**: Exploring the scholars' perceptions, experiences, and perspectives on DSI and the research agenda.
- **DSI Research Section**: Seeking the scholars' opinions, suggestions, and recommendations regarding potential strategies and future directions related to DSI.
- **Debriefing and Demographic Information**: Gathering basic demographic details such as age, gender, educational background, and professional experience.

Time	Questions / Information
General DSI Research Agenda Section	
2 min	*Explanation of the background of the interviews and reference to data processing clarification* • Possibility of recording Teams meeting / audio recording? • Note on anonymization of information and further processing of interview content
3 min	• Can you briefly introduce your professional background? • What research topics are central to you?
5 min	• How would you define DSI? *Detailed presentation of Digital Social Innovation, the study, and the research questions*
25 min	• Comments, feedback on the existing research questions
DSI Research Section	
10 min	• The current portfolio of research questions in the Research Agenda is based on an extensive literature review of adjacent domains. • Do you see a need for expansion or other highly relevant research questions in the field of DSI that must not be missing from this research agenda? • Do you see a need for prioritization among the different questions?
10 min	• In the IS community, the contribution of IS to sustainable development is still considered relatively small. However, the potential of digital technologies is immense. DSI also represents a central lever for achieving the UN SDGs. • What do you consider to be the central challenges in DSI research? What needs to happen, what is missing, to make research in this area even more pioneering? *OR:* What do you consider to be the central challenges in your research area to make research even more pioneering for sustainable development? Which of these challenges are also central for DSI?
10 min	• While the field of DSI is relatively new, it has evolved from longer-standing research streams such as digital innovation, social innovation, or Green IS/IT. Therefore, for the advancement of the field, it is crucial not to reinvent the wheel everywhere but to also draw on existing theories and insights from adjacent areas where possible. • What perspectives, theories, and insights from your research domain do you see as relevant for DSI research?
Debriefing & Demographic Information	
2min	• Age, Gender • Years of experience in research • Current role

Table 51: Interview Guide for Digital Social Innovation

Appendix F.3 Interview Feedback

Appendix F.3 presents the central DSI research agenda feedback points incorporated during the refinement loops and details the respective section. For conciseness, we do not include feedback points on changing the wording of research pathways.

ID	Feedback	Included In
R1	• Include trade-off between the different sustainability dimensions	Research Agenda
R2	• Include a table to subsume the research pathways and their goals	Research Agenda
	• Include ecosystems research stream in the research agenda	Research Agenda
	• Include a call for action on the role of the IS discipline to bring together digitalization, the economy, and sustainability	Conclusion
R5	• Delineate questions to Qureshi et al. (2021)	Discussion
	• Integrate research pathways for each cluster	Research Agenda
R6	• Expand platform focus with insights from digital ecosystems research	Research Agenda
	• Sharpen argumentation on why the research pathways address actions, outcome, or the environment, respectively	Research Agenda
	• Integrate the rebound effect	Research Agenda
	• Integrate the downsides of digital technologies	Research Agenda
R7	• Differentiate the characteristic "social" from the dimension "social innovation" • Change to people, planet, profit	Research Clusters
	• Discuss that the research pathways are representative for a variety of research questions and are not meant to claim completeness	Research Agenda
R8	• Differentiate the characteristic "social" from the dimension "social innovation"	Research Cluster
	• Integrate at least one research pathway for each cluster • Include the structure of the clusters in the research agenda	Research Agenda
R9	• Discuss which research pathways are DSI specific and which are not	Conclusion
R10	• Include a time perspective in the research pathways	Conclusion
	• Discuss dependencies between research pathways • Include limitation that the research pathways are not brough into a chronological order	Conclusion

Table 52: Feedback Implemented in Course of the Digital Social Innovation Expert Interviews