Gather your employees:
Digital transformation in incumbent firms

Insights from the Norwegian grid sector

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Abstract

Digital transformation is necessary for many incumbent firms to stay relevant and competitive in the digital era. It is, however, well documented that digital transformation can be challenging for incumbent firms because it requires a continuous balancing between established practices and new opportunities and typically implies a transformation of the entire workforce. Moreover, despite the increased attention on digital transformation in information systems research, and the fact that the concept has been widely embraced in society at large, there are still several unresolved issues regarding the theorization, nature, and implications of this broad and encompassing phenomenon. In particular, the employee dimension of digital transformation has received limited attention in information systems research. Employees are subject to be heavily affected by the changes following digital transformation and at the same time have the potential to deeply influence the direction and success of the transformation. Against this backdrop, the overarching research question of this thesis is: *How should incumbent firms involve their employees in their digital transformation?*

To answer the research question, I first build on relevant information systems literature to provide an overview and understanding of what digital transformation means and entails for incumbent firms, present common drivers, facilitating conditions, and implications of digital transformation, and discuss how digital transformation differs from traditional information technology-enabled organizational transformation. Then, I review and present literature incorporating the employee dimension in digital transformation research, which emphasizes the importance of employee involvement during digital transformation and sets the basis for answering the research question empirically.

Then, in the four empirical articles included in this thesis, I address different aspects of digital transformation in incumbent firms and explore directly or indirectly why and how incumbent firms should involve their employees in the digital transformation. I have chosen a qualitative research approach, and in each article, I build on insights from a longitudinal case study at an incumbent firm in the midst of a digital transformation; the Norwegian grid company "GridCo". Through spending one to three days a week with GridCo for almost two years, I collected rich data through interviews, observations, and archival data, which enabled me to gain in-depth insight into the organization and their digital transformation.

With my research I aim at contributing to the information systems field and academic conversation on digital transformation, as well as to practice, by delineating important aspects of digital transformation in incumbent firms, shedding light on the importance of employees in such transformations, and illustrating ways in which incumbent firms can involve their employees in their digital transformation. In addition, each individual article offers specific theoretical implications for information systems research and valuable insights for practitioners engaged in or planning to embark on a digital transformation.

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Introductory chapter

1. Introduction

Following pervasive and rapid digital technology development, firms are faced with ongoing changes in environmental and competitive conditions and new customer expectations and behaviors. To stay relevant and competitive in the digital era, many incumbent firms see themselves forced to partly or completely alter the way they do business (Sebastian et al., 2017). Digital transformation, then, is a process by which firms aim at improving their business through organizational change and leveraging digital technologies (Vial, 2019), motivated by technological advances and changes in environmental contexts (Wessel et al., 2020).

As the phenomenon of digital transformation has gained increasing attention in both practice and information systems (IS) research in recent years (Vial, 2019; Wessel et al., 2020), many have pondered whether digital transformation truly reflects something new, as we have already been witnessing information technology (IT)-enabled organizational transformations (ITOT) for decades. There are, however, several ways in which digital transformation differs from ITOT (Li et al., 2018; Wessel et al., 2020). For instance, the technology underlying the transformation has changed. Whereas ITOT mainly concerned implementation of single or a few cases of internal information systems such as enterprise resource planning (ERP) systems to improve or streamline existing business processes (Li et al., 2018), digital transformation implies integration of several digital technologies (Reis et al., 2018; Wessel et al., 2020), often in combination (Bharadwaj et al., 2013; Vial, 2019), to explore new sources of value creation, leading to changes in the organizations' business models, and in some cases, even fostering new organizational identities (Wessel et al., 2020). Moreover, the pervasive character of digital technologies—diffusing organizational boundaries—implies the "digital" becoming a concern of the entire organization, not just the IT department (Berente & Recker, 2021).

In this thesis, I explore digital transformation in incumbent firms. Following Chanias and colleagues (2019), I understand incumbent firms as established companies belonging to traditional industries; companies that perhaps have been successful in the pre-Digital Age, but to which the digital era poses an existential threat (Chanias et al., 2019). It is well documented that digital transformation can be challenging for incumbent, non-born-digital firms (Chanias et al., 2019; Sebastian et al., 2017; Svahn et al., 2017; Warner & Wäger, 2019; Yoo, Henfridsson, et al., 2010). While born-digital firms, such as Google and Amazon, can exploit networking for rapid growth (Parker et al., 2016), incumbent firms evolve more slowly and to a greater extent have to combine digital and physical elements (Bygstad et al., 2020) in their digital transformation, continuously having to balance new opportunities with established practices (Svahn et al., 2017). Accordingly, it is of particular interest to study digital transformation in the context of incumbent firms. For these firms, digital transformation implies a holistic organizational transformation enabled by digital technology (Chanias et al., 2019), which typically also requires a transformation of the entire workforce (Eden et al., 2019).

Despite the increased attention on digital transformation in IS research, and the fact that the concept has been widely embraced in society at large, there are still several unresolved issues regarding the theorization (Markus & Rowe, 2021), nature, and implications (Vial, 2019) of this broad and encompassing phenomenon. From the current discourse, we have learned that digital transformation represents a prolonged process consisting of several combined digitalization efforts and organizational change initiatives (Heilig et al., 2017; Osmundsen et al., 2018a), which researchers recommend should be rooted in a digital business strategy (Bharadwaj et al., 2013). To initiate, coordinate, and oversee digital initiatives and the overall digital transformation, incumbent firms often establish digital innovation units or nominate chief digital officers (CDOs; Haffke et al., 2016). Furthermore, a digital transformation often requires a cultural change in the organization toward a digital culture characterized by willingness to learn and openness to change (Hartl & Hess, 2017).

Yet, there is still a need for a deeper empirical understanding (Vial, 2019) of, for instance, the contributors, challenges, and effects of digital transformation in incumbent firms (Heavin & Power, 2018; Nwankpa & Roumani, 2016). In particular, the employee dimension of digital transformation has received limited attention in IS research (Kensbock & Stöckmann, 2020; Kozanoglu & Abedin, 2020). By employee, I am referring to that such as the general, operational employee; the accountant having to adjust to having a robot as a new coworker, the waitress whose tasks of receiving and accepting orders are now performed by self-service mobile applications, and the electrician learning to pilot a drone to inspect aerial power lines.

To illustrate why it is important to understand the employee dimension of digital transformation, it is useful to consider the two words constituting the phenomenon separately: "digital" and "transformation." *Digital* concerns the digital technologies by which the employee is surrounded and interacting with during and following the digital transformation (Nambisan et al., 2020). Just as one may consider IS as consisting of structures, people, technology, and tasks (Bostrom & Heinen, 1977), "digital" also holds social dimensions and concerns the entire organization (Berente & Recker, 2021). Not only do the employees have to apply and manage new digital technologies during and because of digital transformation; they are also increasingly involved in the planning, development, and implementation of these digital technologies.

Transformation, then, in its general meaning, denotes a complete change in character of something,[1] in this context, an organization. Completely changing an organization would both affect and have to involve the employees, and from neighboring research fields such as organizational studies, leadership,

[1]Adopted from Cambridge Dictionary: https://dictionary.cambridge.org/dictionary/english/transformation

and change management, we have learned that one cannot succeed with organizational change and transformation if one does not succeed in the employee dimension and involve the employees (e.g., Kotter, 1995).

Therefore, I consider digital transformation a socio-technical (Bostrom & Heinen, 1977) process and phenomenon (Bockshecker et al., 2018; Schmid et al., 2017). It concerns the entire organization (Kensbock & Stöckmann, 2020) and involves organizational actors within all business areas and across all levels. Employees are subject to be heavily affected by the changes following the digital transformation and at the same time have the potential to deeply influence the direction and success of the transformation. Against this backdrop, the overarching research question of this thesis is: *How should incumbent firms involve their employees in their digital transformation?*

To answer the research question, I have included four empirical articles in this thesis—all of in which I explore various aspects of digital transformation in incumbent firms and at the same time consider the employee as focal in the transformation—to understand ways in which employees may react to or be affected by the digital transformation, and how involving the employees in the transformation process and initiatives may contribute to incumbent firms' digital transformation success. I build on insights from a longitudinal case study at an incumbent firm in Norway—referred to as "GridCo"—one of the largest and oldest grid companies in Norway. The grid sector in Norway has traditionally been very stable, and because it is not economically viable to build adjacent grid networks, each grid company has held a safe and natural monopolistic position for decades. However, with the recent developments within digital technology, increased electrification, and advancements in electricity distribution, GridCo acknowledged that they needed a digital transformation.

I was fortunate to get the opportunity to spend one to three days a week with GridCo for almost two years; collecting data, getting to know the organization, and learning about their digital transformation. With the insights from my research, I collectively hope to contribute to the IS field by increasing our common understanding of digital transformation in incumbent firms and shedding light on the ways in which employees can be affected by and influence and take part in the digital transformation.

The remainder of this introductory chapter is structured as follows. In Section 2, I introduce relevant concepts and literature related to digital transformation, and in Section 3, I draw on IS literature to explore the employee dimension of digital transformation in more detail. In Section 4, I present the methodological choices underlying my research, including research paradigm, research methods, and an introduction to the case setting. I also present the methods I applied in data collection, treatment, and analysis—with a focus on adding to the descriptions already provided in the articles—and discuss the trustworthiness of the research findings. Then, I briefly present the four articles in Section 5, followed by a discussion of contributions and implications for research and practice in Section 6 and, finally, concluding remarks in Section 7.

2. Introducing relevant concepts and literature on digital transformation

In each article I cover different aspects of digital transformation and build on different theoretical foundations and research streams within the IS literature, which are thoroughly reviewed and presented for each article. Instead of repeating the theoretical perspectives underlying each article, in the current section I present relevant IS literature and clarify central concepts related to digital transformation, and in the following section (Section 3), I build on the literature to further explore the employee dimension of digital transformation. The overview and insights provided in these two sections form the basis for answering the overarching research question of this thesis.

One of the first activities I engaged in during my PhD journey was to conduct a systematic literature review with assistance from my supervisors Jon Iden and Bendik Bygstad. Based on pre-defined criteria for search and quality assessment, we reviewed 26 journal papers and 43 conference papers discussing or conceptualizing digitalization and published between 2010 and 2017 in IS outlets. The aim of the literature review was to unpack the concept of digitalization—the phenomenon I initially intended to focus on in my research—based on relevant and recent IS literature. However, while reviewing the literature, I realized that the concept of *digitalization* was frequently discussed alongside other concepts, including *digital transformation*. Although the two concepts represent separate phenomena, they are often conflated, and accordingly, in this section I seek to provide a clarification of these concepts. It was also through working on this literature review that I came to find the concept of digital transformation under-investigated, which resulted in a refocusing of my research projects towards the broader perspective of digital transformation.

The literature review generated two often-cited conference papers. In the first conference paper we addressed the question "how are the concepts digitalization, digital innovation, and digital transformation conceptualized in prevailing literature?" (Osmundsen et al., 2018b), which we presented at the Norwegian conference for organizations' use of information technology (NOKOBIT) in September 2018. The main contribution of this paper was a conceptual model we developed and discussed to clarify the links (and differences) between the concepts of digitization, digitalization, digital innovation, and digital transformation. In the second conference paper we dove a bit deeper into the reviewed articles that (a) where empirical, and (b) addressed digital transformation. Based on the insights from these 21 empirical articles, we outlined what was found as common drivers, success factors, and implications of digital transformation (Osmundsen et al., 2018a). We presented this paper at the 12th Mediterranean Conference on Information Systems (MCIS), also in September 2018. In the following, based on the initial literature review, the conference articles, and additional IS literature, I seek to clarify the concepts of digitalization and digital transformation, with a focus on the latter concept. First, however, let me explain what is meant by digital technology, which forms the basis for both digitalization and digital transformation.

2.1 Digital technology

Digitalization and digital transformation are enabled by, or build on, digital technology. According to Bygstad and colleagues (2019), digital technologies should not be considered as tools, but rather as valuable resources in digital transformation, in the same manner as human and monetary resources. Following the definition of Bharadwaj and colleagues (2013), digital technologies refer to "combinations of information, computing, communication, and connectivity technologies" (Bharadwaj et al., 2013, p. 471). When describing digital transformation, the literature emphasizes novel and modern digital technologies; what is often referred to as SMACIT (social, mobile, analytics, cloud, and Internet of things (IoT)) technologies (Sebastian et al., 2017; Vial, 2019). Although this acronym does not cover all digital technologies, it gives a good indication of the types of digital technologies involved in digital transformations. In Article 1 we also provide an overview of typical digital technologies involved in digital transformations (Table 2 in Article 1).

As IS professors Nicholas Berente and Jan Recker neatly compared "digital" to "IT" in their podcast *this IS research*; IT is what the IT department does, and digital is what the entire organization does (Berente & Recker, 2021). Researchers have in different ways highlighted the unique characteristics of modern digital technologies, clearly distinguishing them from traditional IT. For instance, Yoo and colleagues (2010) explained how digital technologies hold distinct characteristics of *reprogrammability*, *homogenization*, and *self-referentiality*. By this the authors referred to how digital technologies can be designed to obtain different features and perform a wide array of functions. They can store, transmit, process, display, and share a variety of information, and the self-referential nature of the digital technologies accelerate their areas of application (Yoo, Henfridsson, et al., 2010). Kallinkos and colleagues (2013) used the terms *editable*, *interactive*, *open*, and *distributed* (Kallinkos et al., 2013) and Brynjolfsson and McAfee (2014) described digital technology as *exponential* and *combinatorial* (Brynjolfsson & McAfee, 2014). More recently, Bygstad and colleagues (2019) suggested digital technologies best be characterized as *global*, *general*, *generative*, and *generous* resources. Independent of the terminology, it is clear that digital technologies hold unique characteristics. Together with improved price-performance ratios and increasing amounts and quality of data (Fitzgerald et al., 2014; Yoo, Henfridsson, et al., 2010), waves of digital change are occurring ever more frequently and rapidly (Westerman et al., 2014), representing either digital threats or sources of digital opportunities for incumbent firms (Chanias et al., 2019; Sebastian et al., 2017; Wessel et al., 2020).

2.2 Digitalization: An introduction

Digitalization has become a household term over recent years, used in situations ranging from daily conversations, political discussions, and the academic discourse. Still, there exist a variety of interpretations of the meaning of the concept in its daily use, just as there exist a variety of definitions of the concept in the IS literature (Osmundsen et al., 2018b). The most common understanding of digitalization, however, seems to build on a conceptualization that derived from a research workshop in

2010 on *Digital Changes in Innovation Research*, where the authors in reporting on the workshop defined digitalization as "the transformation of socio-technical structures that were previously mediated by non-digital artifacts or relationships into ones that are mediated by digitized artifacts and relationships" (Yoo, Lyytinen, et al., 2010, p. 6). Building further on this definition by Yoo and colleagues (2010), I use the term digitalization to refer to *processes of applying digital technology to alter one or multiple socio-technical structures* (Osmundsen et al., 2018a, 2018b). In this context, a structure refers to anything composed of parts arranged together, such as a process, service, user-experience, work arrangement, etc. Socio-technical structures, then, refer to both the social (e.g., human interactions, relationships, norms, etc.) and technical (e.g., technology, tasks, routines, etc.) aspects of the structure.

I also find it appropriate to mention how digitalization is distinct from *digitization*; two concepts that are often confused with one another and used interchangeably in both practice and academia (Osmundsen et al., 2018b). Digitization regards the process of converting data and components from analog or physical to digital (Hylving & Schultze, 2013; Yoo, Henfridsson, et al., 2010; Yoo, Lyytinen, et al., 2010), which is a mere technical process. Digitalization on the other hand, is a socio-technical process (Mihailescu & Mihailescu, 2017; Yoo, Lyytinen, et al., 2010). Digitalization implies that not only do the technical or material aspects of the structure change (i.e., the technical process of digitization)—it also involves a reconfiguration of roles, relationships, practices, and organizational boundaries (Gebre-Mariam & Bygstad, 2019; Osmundsen et al., 2018b). To illustrate this with an example, Mihailescu and colleagues (2015) studied how implementation of electronic patient records (EPR) altered business processes and introduced new possibilities in hospitals. While the transforming of patient records from paper to electronic format represents digitization, digitalization, in this context, also involves the changes in social aspects following EPR, such as new ways of combining the patient records with other tools and devices, new physical work arrangements, and new interactions among healthcare personnel and with patients (Mihailescu et al., 2015).

2.3 Digital transformation: An introduction

If an organization, over time and to a certain extent, applies digital technology to alter several socio-technical structures, it may lead to significant changes to how business is conducted (Osmundsen et al., 2018b, 2018a). In other words, digitalization can over time lead to digital transformation. Inversely, digital transformation typically involves one or more digitalization projects or initiatives. Nonetheless, it is important to remember that digital transformation exceeds the mere digitalization of products, services, and processes, and requires organizational transformation (Hartl & Hess, 2017; Osmundsen et al., 2018b, 2018a). As Singh and Hess (2017) emphasized, the notion "transformation" represents a comprehensive and encompassing change, one that influences several organizational dimensions and might require a redefinition of strategy, new organizational routines, and changed business models, where the outcome is significantly different from the original state (Berghaus & Back, 2017).

As with digitalization, a variety of definitions and conceptualizations exist also for the concept of digital transformation. Vial (2019) viewed digital transformation as a process aiming to improve an entity by triggering significant changes to its properties through digital technologies. Hanelt and colleagues (2020) described it as an organizational change triggered and shaped by digital technologies. In a similar vein, Chanias and colleagues (2019) viewed digital transformation as a holistic business transformation enabled by digital technology, and Tekic and Koroteev (2019) described it as a major transformational change based on integrations of digital technologies to survive in the digital era. What is common among the different conceptualizations is the emphasis on organizational change and digital technology (Osmundsen et al., 2018b; Wessel et al., 2020). Drawing on these conceptualizations, I understand digital transformation as *a holistic organizational change driven by, built on, or enabled by digital technology and data, partly or completely altering how business is conducted*. Unlike most definitions proposed in the IS literature, I have added “data” as a driver for change, because I believe that the increasing number of data available for firms could also serve as enablers for digital transformation if utilized and managed well.

Although it is most common to consider digital transformation as an organizational phenomenon, some researchers have pointed out that digital transformation can occur in entire industries as well (Berghaus & Back, 2017; Osmundsen et al., 2018a; Piccinini et al., 2015; Vial, 2019), referring to major digital trends enabling new business models and affecting the relations between industry actors (Berghaus & Back, 2017). In this thesis, however, I focus on digital transformation on an organizational level.

2.4 Digital transformation versus IT-enabled organizational transformation

Digital transformation has received increasing attention in IS research in recent years (Vial, 2019; Wessel et al., 2020). It is important to clarify, however, what differentiates digital transformation from traditional IT-enabled organizational transformation (ITOT), which we have witnessed in practice and which has been explored in research within the IS and organizational fields for decades (Li et al., 2018; Wessel et al., 2020).

Where traditional ITOT mainly concerned implementation of single or a few instances of internal information systems, such as ERP or customer relationship management (CRM) (Li et al., 2018; Wessel et al., 2020), digital transformation is driven by accelerated digital technology development (Osmundsen et al., 2018a) and involves integration of several novel digital technologies in combination (Bharadwaj et al., 2013; Vial, 2019). Further, where traditional ITOT focused on leveraging technology to streamline and improve existing business processes, reduce costs (Li et al., 2018), and support the firm’s existing value propositions (Wessel et al., 2020), digital transformation implies leveraging several digital technologies combined to uncover new paths of value creation (Hanelt et al., 2020; Vial, 2019) and redefine the firm’s value propositions (Wessel et al., 2020).

Furthermore, digital technology has evolved to become pervasive and ubiquitous (Yoo, 2013), and the digital technologies involved in digital transformation are often complex and even disruptive (Karimi & Walter, 2015; Nambisan et al., 2019; Tim et al., 2020) (however, not always disruptive; see e.g., Andriole, 2017). Accordingly, when describing digital transformations, the emphasis is often on the transformational implications digital technology has for business (Nambisan et al., 2019; Tim et al., 2020). The digital technology underlying this type of organizational transformation exhibits new properties and unique characteristics, as described in Section 2.1. Moreover, the digital technology has evolved over time, is now available and applicable to a much broader spectrum of areas, and has greater organizational implications (Osmundsen et al., 2018b).

Finally, differences can also be found between digital transformation and ITOT regarding scale and pace (Hartl & Hess, 2017; Vial, 2019). Regarding pace, digitalization, digital innovations, and digital transformations are occurring much faster and more frequently than only a few decades ago (Osmundsen et al., 2018b). Regarding scale, digital transformation affects organizations more holistically (Hartl & Hess, 2017) than we have seen in ITOT, and hence, where ITOT was mainly a concern of the IT department, digital transformation concerns the entire organization (Berente & Recker, 2021). Even though we have “seen this before,” it is certainly new that it is happening in so many organizations. Banks, insurance-companies, and even pizza chains explain how they are moving away from their traditional business models to business models based on digital technology. Banks are no longer traditional banks, but tech companies (Osmundsen et al., 2018b). Accordingly, unlike ITOT, digital transformations are occurring in a wider range of organizations, in every industry, and even in the public sector (Osmundsen et al., 2018b), as incumbent firms are increasingly forced to partly or completely change their business to stay relevant and competitive in the digital era (Nambisan et al., 2019; Sebastian et al., 2017).

2.5 Drivers behind digital transformation

Following pervasive and rapid digital technology development, organizations today are faced with ongoing changes in environmental and competitive conditions, as well new customer expectations and behaviors. To survive, organizations need to embrace the digital era as a source of opportunity rather than a threat (Wessel et al., 2020) and leverage digital technology development. This requires digital transformation (Hartl & Hess, 2017). In an earlier literature review (Osmundsen et al., 2018a), we found the most common drivers of digital transformation to be changes in customer behaviors and expectations, digital shifts in the industry, the changing competitive landscape, and in some cases also regulatory changes (Berghaus & Back, 2017; Osmundsen et al., 2018a). Vial (2019) also pointed out the increasing availability of data as a driver for digital transformation. With increased development and application of digital technologies follows an increased generation of data, which firms should seek to exploit to increase efficiency and meet customer needs (Vial, 2019). These drivers are all changes occurring in the environmental contexts of organizations, and hence we could perhaps argue that digital transformation to a large extent is externally driven (Li et al., 2018), motivated by, and as responses to, changes occurring in the environment (Vial, 2019; Wessel et al., 2020).

2.6 Digital transformation facilitating conditions

Embracing digital transformation is not straightforward. In Osmundsen et al. (2018a) we referred to "success factors" to denote different factors that IS researchers have highlighted as important for firms in their digital transformation. However, I am not particularly fond of the term "success factor", as it seems to imply success in digital transformation if these elements are in place. Instead, I use the term "facilitating conditions" in this thesis: cultural changes, leadership, alignment between business and IT, digital business strategy, structural changes, dynamic capabilities, and employees (Osmundsen et al., 2018a).

Digital transformation typically requires *cultural changes*, as well as changes to how *leadership* is conducted and enacted. Regarding culture, Hartl and Hess (2017) found openness to change and customer centricity as two of the most important cultural values for digital transformation, and emphasized the importance of agility (rather than control) to support the digital transformation process (Hartl & Hess, 2017). Kane and colleagues (2016) further highlighted risk affinity, experimentation, and talent focus as important digital cultural values. Regarding leadership, digital transformation may lead to changes in the nature of and ways in which leadership is exerted, as well as introduce new leadership roles (Schwarzmüller et al., 2018; Vial, 2019). I discuss both culture and leadership in the context of digital transformation in more detail in Section 3.4.

Digital transformation requires an *alignment between business and IT*, which has been a topic of IS research for a long time (Yeow et al., 2017). Venkatraman and colleagues (1993) argued that in order to realize values from IT investments and to obtain competitive success, organizations needed to align the business domain (i.e., business strategy, organization infrastructure and processes) and the IT domain (i.e., IT strategy, IS infrastructure and processes) (Henderson & Venkatraman, 1993; Venkatraman et al., 1993). Digital transformation implies the role of IT becoming increasingly strategic and intertwined with business (Haffke et al., 2016), and hence, aligning business and IT becomes ever more important (Yeow et al., 2017).

As a result, many organizations have moved towards a *digital business strategy* (DBS); a fusion of the IT strategy and business strategy (Bharadwaj et al., 2013; Vial, 2019). Bharadwaj and colleagues (2013) define DBS as an "organizational strategy formulated and executed by leveraging digital resources to create differential value" (Bharadwaj et al., 2013, p. 472). A DBS is found to be important for organizations to achieve digital transformation (Leischnig et al., 2017), and inversely, a digital transformation is also depicted as necessary to accomplish the objectives of a DBS (Nwankpa & Roumani, 2016).

To achieve better alignment between business and IT, digital transformation often requires *structural changes* to the organization—in particular to achieve cross-functional collaboration (Vial, 2019). In this context, researchers have recommended creating a separate digital unit, independent from the rest of the organization (Dremel et al., 2017; Iden & Bygstad, 2021; Vial, 2019). For instance, Iden and Bygstad (2021) studied the digital transformation at Nordic Choice hotels; a firm that established a new digital unit as a separate company to lead the digital transformation and realize the DBS of the hotel chain (Iden & Bygstad, 2021) and also to address the changing skill and resource requirements to compete in the digital era (Bygstad et al., 2020).

Developing and leveraging *dynamic capabilities* is also considered crucial for achieving digital transformation (Berghaus & Back, 2017; Karimi & Walter, 2015; Leischnig et al., 2017). Dynamic capabilities refer to an organization's ability and capacity to sense opportunities and threats in the environment, seize the relevant opportunities, and manage threats through transformation (Teece, 2007). In the context of digital transformation, this implies an ability to look beyond existing operations to understand environmental dynamics, technological developments, and changing customer needs (i.e., sensing). Seizing then implies the ability to mobilize skills and resources to leverage opportunities, and transformation implies reconfiguring resources to mobilize, motivate, and inspire for change and manage threats (Iden & Bygstad, 2021). Accordingly, through dynamic capabilities, firms are posited to be better equipped to identify and respond to opportunities and threats in the environment by transforming the organization (Iden & Bygstad, 2021; Karimi & Walter, 2015; Leischnig et al., 2017).

As the digital transformation changes the structure and culture of the organization, *employees* are led to assume roles outside their traditional functions (Vial, 2019). Where the IT people are expected to become more business-savvy (Dremel et al., 2017), employees outside the IT function are increasingly being involved in technology-intensive projects and situations (Vial, 2019; Yeow et al., 2017). As digital transformation inherently implies integration of digital technologies, enabling new forms of automation and decision-making, new competencies are required among existing and new employees (Butschan et al., 2019; Colbert et al., 2016; Dremel et al., 2017; Hess et al., 2016; Vial, 2019). Less is known, however, about which competencies are particularly relevant in digital transformation (Butschan et al., 2019), or how to best accompany employees through this transition (Karimi & Walter, 2015; Singh & Hess, 2017; Vial, 2019). Moreover, to reach the full potential of the digital transformation, the organization needs engaged employees (Mihailescu & Mihailescu, 2017), which is perhaps best achieved by actively involving the employees in the digital transformation efforts (Mueller & Renken, 2017; Petrikina et al., 2017). I discuss the employee dimension of digital transformation in more detail in Section 3.

2.7 Implications of digital transformation

In Osmundsen et al. (2018a) we highlighted a reformed IS organization, new business models, and effects on outcome and performance as implications of digital transformation. Vial (2019) distinguished between positive and negative implications of digital transformation, because although we mainly focus on the positives, digital transformation may indeed have undesirable effects as well, particularly in the domain of security and privacy following pervasive use of digital technologies (Piccoli et al., 2017; Vial, 2019). Regarding the more desirable outcomes, digital transformation is found to increase organizations' operational efficiency through, for instance, automating and improving business processes (Vial, 2019). Moreover, digital transformation is found to be positively associated with several dimensions of firm performance (Nwankpa & Roumani, 2016; Vial, 2019) and innovation (Ferreira et al., 2019). Still, I would argue that just as there are no "one size fits all" solutions for how organizations should embrace digital transformation, there are also no exact answers of the outcomes and implications of any firms' digital transformation. The outcomes would for instance depend on *what* is being transformed, as in the type of business and organization. In this thesis I focus specifically on digital transformation in incumbent firms.

2.8 Digital transformation in incumbent firms

By *incumbent firms*,[2] I refer to established, often old and ponderous companies in traditional industries that are facing existential challenges in the digital era (Chanias et al., 2019). Many incumbent firms have been successful and held strong positions in the pre-Digital Age; however, the new digital reality has made it difficult for several of them to change in a timely manner and avoid losing value and relevance (Tekic & Koroteev, 2019). GridCo, the case organization I have engaged with in my research, represents an incumbent firm, and one in the midst of a digital transformation (Osmundsen, 2020) (I provide more details on GridCo in Section 4.3). Other examples of incumbent firms that have undergone digital transformations include for instance automotive companies that have faced challenges from new digital competitors penetrating the industry, and where physical products are increasingly permeated with digital layers (Dremel et al., 2017; Piccinini et al., 2015; Remane et al., 2017; Svahn et al., 2017), or hotels having to meet competition from Internet-based platform companies such as online travel agencies (e.g., Hotels.com and Booking.com) (Bygstad et al., 2020). Examples also exist of incumbent firms that have not managed to digitally transform to stay relevant in the digital era, such as the most commonly used example of Kodak, where the organization's core capabilities prevented digital

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[2]Notions such as established firms (e.g., Osmundsen, 2020), pre-digital organizations (e.g., Chanias et al., 2019), traditional firms (e.g., Verhoef et al., 2021), existed firms (e.g., Jin et al., 2020), or big old companies (e.g., Sebastian et al., 2017) are used interchangeably in the literature. In this thesis, I use the term "incumbent firms."

transformation (Lucas Jr. & Goh, 2009; Vial, 2019), or Blockbuster, one of the most iconic brands in the video rental space, which was unable to transition towards a digital model and meet the competition from streaming companies such as Netflix (Goh, 2017; Kafka & Molla, 2020). A more recent example is Toys 'R' Us, one of the largest toy store chains, which filed for bankruptcy in 2017. The company relied on Amazon for selling their toys and missed the opportunity to develop their own e-commerce and digital presence (Goh, 2017); however, in 2017 the Toys 'R' Us brand re-emerged through the company Tru Kids, and in 2020, they again partnered with Amazon (Verdon, 2020).

Incumbent firms' challenges in the digital era may stem from the increased and dynamic competition caused by new digital entrants and digital ecosystems (Bygstad et al., 2020) or managements' lack of consideration of the possible benefits of digital technologies (Vial, 2019). Moreover, the literature emphasizes incumbent firms' embeddedness in existing relationships with customers and suppliers and rigid processes (Andriole, 2017; Vial, 2019) as hinderers of digital transformation, as well as their reliance on established cultures (Töytäri et al., 2017; Vial, 2019), knowledge, capabilities, and beliefs from the non-digital environment (Tekic & Koroteev, 2019). Such reliance on established assumptions could lead to inertia (Vial, 2019), constraining them from engaging in digital initiatives (Engesmo & Panteli, 2020; Westerman & Bonnet, 2015). In fact, in his literature review, Vial (2019) found inertia to be one of the most common barriers to digital transformation, where existing resources and capabilities are constraining for innovation. Another common barrier for incumbent firms' digital transformations is found to be resistance among employees (Vial, 2019), which in the literature is discussed as possibly stemming from inertia (Schmid et al., 2017), or the pace and ways in which new digital technologies are introduced to the employees as part of the digital transformation (Fitzgerald et al., 2014; Svahn et al., 2017). I address employees' reactions to digital transformation in more detail in Section 3.2.

In addition to common barriers of inertia and resistance (Vial, 2019), the literature is clear on digital transformation being challenging for incumbent firms (e.g., Andriole, 2017; Sebastian et al., 2017; Svahn et al., 2017; Warner & Wäger, 2019). While born-digital firms, such as Google and Amazon, are characterized by flexible management structures (Debois, 2011) and can exploit networking for rapid growth (Parker et al., 2016), incumbent firms are less flexible, evolve more slowly, and to a greater extent have to combine digital and physical elements (Bygstad et al., 2020) in their digital transformation. As a result, incumbent firms have to continuously balance new opportunities with established practices (Svahn et al., 2017) as well as the need for strategic agility in existing structures and practices (Schmid et al., 2017).

For incumbent firms, digital transformation implies a holistic organizational change, where implementation of new digital technologies serves to meet challenges in the digital era and at the same time result in extensive changes to the organizations' products, services, operations, and business models (Chanias et al., 2019). Digital transformation is a socio-technical phenomenon (Bockshecker et al., 2018;

Schmid et al., 2017) and, hence, cannot be considered on the basis of digital technologies only. Digital transformation is just as much about changes to the organizations' culture and identity (Töytäri et al., 2017), strategic choices (Chanias et al., 2019; Kane et al., 2015), and value propositions (Sebastian et al., 2017; Wessel et al., 2020), which for incumbent firms, and unlike born-digital firms, implies rethinking the fundamentals of the organization. Moreover, for incumbent firms, digital transformation typically requires a transformation of the entire workforce (Eden et al., 2019) and affects organizational actors within all business areas (not merely the IT function) and across all organizational levels (not merely managers) as new digital technologies are diffused into existing work practices (Kensbock & Stöckmann, 2020).

3. Employees during digital transformation

MIT Principal Research Scientist George Westerman reminds us in his essay *Digital Transformation Needs a Heart* that "we cannot forget that it is people who make companies work" (Westerman, 2016, p. 3). Both academics and practitioners agree that the employee dimension is crucial for digital transformation success. In an annual report on *The State of Digital Transformation*, the analyst firm Altimeter highlighted the importance of happy and engaged employees for successful digital transformation: "Helping employees develop critical digital literacy—and training, retraining, and engaging them around a digital transformation vision—empowers them and turns them into capable allies in your transformation and innovation efforts" (Solis, 2019, p. 27). Tabrizi and colleagues (2019) found that digital transformation was successful in companies where management "focused on changing the mindset of its members as well as the organizational culture and processes before they decide what digital tools to use and how to use them" (p. 5), however; this may prove challenging to accomplish in practice. For instance, the management consulting firm BCG argued, based on their analysis, that managers often fail to consider the human aspect in their digital transformation: "As with any transformation, leaders who guide a digital transformation are often preoccupied with structural and process changes and overlook the people side—only to wonder why the effort failed" (Hemerling et al., 2018, p. 6).

IS research focusing on the employee dimension of digital transformation is still nascent (Kensbock & Stöckmann, 2020; Kozanoglu & Abedin, 2020). To get an overview of what is known from the literature about the employee during digital transformation, I conducted a literature review. I collected and thoroughly read relevant articles from IS journals and IS conference proceedings that included the search terms "digital transformation" and "employee" in their title, abstract, or keywords. From the literature review I observed that IS researchers have focused on different aspects of the employee dimension in the context of digital transformation. Accordingly, for the purpose of this thesis, I have organized relevant IS literature on the employee dimension of digital transformation into four main research streams (see Figure 1): (1) impacts of digital transformation on employees, (2) employee reactions to digital transformation, (3) the importance of employee engagement and approaches to involve employees in the digital transformation, and (4) enabling factors, that is, factors that enable organizations to engage and take the employees into rightful consideration during the digital transformation. In the following, I present relevant literature and insights from each research stream, followed by a summary in Section 3.5.

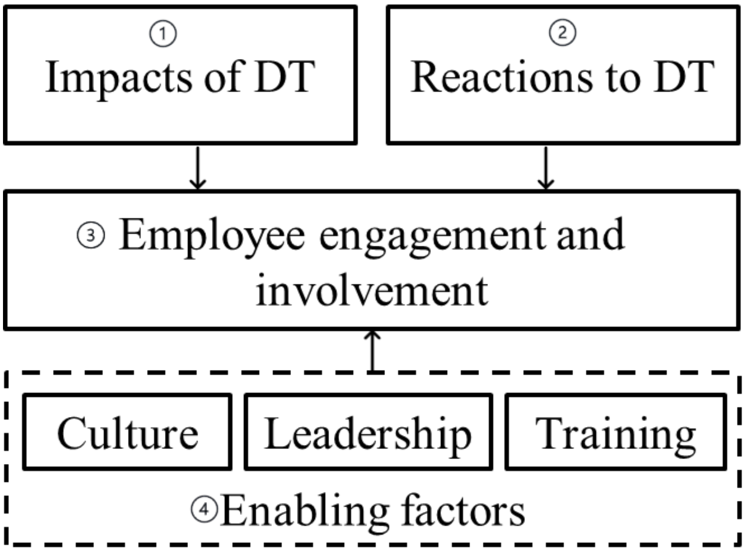

Figure 1. Identified research streams: Employee dimension of digital transformation

3.1 Impacts of digital transformation on employees

Digital transformation inherently implies integration of digital technologies, often in combination. To successfully integrate new technology in an incumbent firm, adjustments to existing organizational processes, structures, and arrangements are necessary. This becomes increasingly apparent as the digital era prompts challenges for incumbent firms to respond to changing customer requirements and dynamic environments. Accordingly, digital transformation has the potential to affect the employees in the organization, both directly and indirectly, through radically changing work environments and routines (Kensbock & Stöckmann, 2020). The first research stream identified focuses on exactly this; the impacts of digital transformation on employees.

Impacts on work design/workplace

One aspect that has been highlighted is how digital transformation involves a redesign of how employees work (Dery et al., 2017). As a consequence of increased digital technologies and the need to respond to changes in the environment, many organizations are required to change the way in which employees work and the conditions under which they do so (Schwarzmüller et al., 2018), what is often referred to as a *digital workplace transformation* (Meske, 2019; Meske & Junglas, 2020). Meske and Junglas (2020) defined digital workplace transformation as when integration of digital technologies causes "significant changes to a variety of work-related aspects: changes to how employees carry out tasks and processes, as well as changes to their social relations within the organization, and subsequently to their overall workplace experience" (p. 1). Understanding how digital transformation affects employees in their workplace involves acknowledging that work is fundamentally social, and that digital transformation affects different employees differently (Meske & Junglas, 2020). The literature emphasizes increased flexibility in working conditions (Foerster-Metz et al., 2018; Kluge et al., 2020; Schwarzmüller et al., 2018), new forms of workplace communication and collaboration (Foerster-Metz et al., 2018; Kluge et al., 2020; Schwarzmüller et al., 2018), and changes to the work-life balance (Foerster-Metz et al., 2018; Schwarzmüller et al., 2018). Moreover, increased use of digital technology is found to have the potential to increase organizational transparency in, for instance, decision-making (Foerster-Metz et al., 2018), the digital transformation process (Sivaraman, 2020), innovation processes (Reibenspiess et al., 2020), and the employee-management dialogue in general (Hildebrandt et al., 2020; Peter et al., 2020). On the other hand, the introduction of digital technologies may also lead to increased performance surveillance (Foerster-Metz et al., 2018). If employees perceive that the digital transformation is accompanied by increased surveillance, it may "cast a shadow on the positive effects of digital transformation on employees" (Kensbock & Stöckmann, 2020, p. 23).

Emotional impacts

The changes induced by digital transformation may affect employees emotionally (Stam & Stanton, 2010; Winasis et al., 2020), as they may have to adopt different mindsets, find new sources of motivation, and rely on other skillsets than what they are used to (Foerster-Metz et al., 2018). The most common emotional effect emphasized in the literature as employees are confronted with massive change is stress (Kluge et al., 2020), or in relation to new technology, what is often referred to as *technostress*, a "modern disease caused by one's inability to cope or deal with ICTs in a healthy manner" (Ayyagari et al., 2011, p. 832). Technostress is found to be more common among younger employees, who are paradoxically typically more motivated for digital transformation compared to their elder colleagues (Gilch & Sieweke, 2020; Kluge et al., 2020). Technostress may influence employees' performance and habits negatively (Meske & Junglas, 2020), and hence, it is important that managers take into account employees' emotions in the digital transformation (von Ohain, 2019). Prevailing literature has identified different antecedents of technostress among employees, one of them being employees' perception of job insecurity (Ayyagari et al., 2011). During digital transformation, employees can experience a feeling of job insecurity—which often relates to a fear of becoming obsolete or a perception that one lacks the competencies required (Ayyagari et al., 2011) following the digital transformation.

Impacts on jobs/labor market

A fear of becoming obsolete is perhaps partly justified considering how digital technology and digital transformations are projected to affect the labor market (Dengler & Matthes, 2018). According to the World Economic Forum's report *The Future of Jobs*, the increasing integration of emerging digital technologies will lead to more than 15% of all roles becoming redundant by 2025 (Zahidi et al., 2020). Other studies have provided disturbing predictions, suggesting that approximately half of all jobs of

2018 would be susceptible to automation in the following 10 to 20 years (Dengler & Matthes, 2018). Frey and Osborne (2017) estimated 47% of the total of jobs in the US to be at risk of automation over the next two decades. In the Norwegian context, Pajarinen and colleagues (2015) estimated one third of Norwegian employment to be highly susceptible to computerization in the next decades. Where typically "middle-skilled jobs such as bank tellers or book keepers" (Schwarzmüller et al., 2018, p. 117) have been predicted to be prone to automation for some time now, more recently, research has also emphasized that emerging digital technologies such as artificial intelligence (AI) will increasingly come to threaten jobs of white collar workers as well (Frey & Osborne, 2017). In the public and academic debates it is typically these negative projections that have been brought to light (Dengler & Matthes, 2018). Hence, it is no wonder employees might experience a fear of becoming obsolete or feel insecure in their jobs (Ayyagari et al., 2011).

On the other hand, as Dengler and Matthes (2018) pointed out, "it is controversial whether the new digital technologies will substitute jobs or create more and new jobs" (p. 304). The authors argued that many studies overestimate the automation probabilities, and that the projections of jobs being eliminated are perhaps not as discouraging as depicted by many. Due to emerging technology following the digital transformation, accompanied by other environmental factors such as globalization (Sousa & Rocha, 2019), increasing sustainability awareness, and demographic change (Dengler & Matthes, 2018; Kluge et al., 2020), new jobs and tasks will arise (King & Grudin, 2020). Moreover, emerging digital technologies may also function to support employees in their existing jobs (Davenport & Kirby, 2016), helping employees perform tasks and informing their decisions (Schwarzmüller et al., 2018). In fact, the World Economic Forum also reported a growth of 13.5% in emerging professions among companies' existing workforce, reflecting the adoption of digital technologies and changes in customer demands (Zahidi et al., 2020). They projected an increasing demand for roles such as data analysts and data scientists, as well as specialists within AI, machine learning, big data, digital marketing, digital strategy, process automation, information security, and IoT (Zahidi et al., 2020). Following this more edifying perspective, organizations will still heavily depend on their human capital during and after digital transformation (Vial, 2019).

Impacts on competency requirements

Accordingly, not all jobs will be substituted by technology; however, many jobs will be transformed. Hence, as a result of digital transformations, old skills may become obsolete, while new ones will be required (Sousa & Rocha, 2019). Concepts such as *digital skills* (Sousa & Rocha, 2019) and *21st century digital skills* (van Laar et al., 2017, 2019) have been suggested and explored in the IS literature, seeking to identify which skills are essential for employees to hold in the digital era. Moving beyond skills, competencies refer to a firm's bundle of its employees' knowledge, skills, and abilities (KSAs) (Peppard & Ward, 2004). Both academia and practitioners agree that digital transformation requires new competencies (Fitzgerald et al., 2014; Hess et al., 2016; Salviotti et al., 2019; Vial, 2019) and that organizations cannot succeed in their digital transformation without qualified employees with the necessary competencies (Cordes & Rosemann, 2020; Salviotti et al., 2019). Digital transformation affects the entire organization, and requires new competencies of employees at all organizational levels and functions (Vial, 2019) for them to keep up with the digital technology advancements (Foerster-Metz et al., 2018), utilize emerging technology to solve increasingly complex tasks (Dremel et al., 2017; Vial, 2019), and help the organization overcome digital transformation challenges (Sousa & Rocha, 2019).

Accordingly, when undergoing digital transformations, firms should take advantage of existing strengths and competencies and, simultaneously, develop relevant competencies and exploit new digital technology (Gupta et al., 2018). However, insight on how firms can accomplish this strategy (Eden et al., 2019) and which competencies are particularly important for firms embracing digital transformation is limited (Butschan et al., 2019; Shahlaei et al., 2017). Butschan and colleagues (2019) offered a valuable starting point for addressing this gap; however, their focus was on industrial IoT (IIoT) and not on digital transformation in general, and there is still a need for more empirical evidence on competencies essential for digital transformation success. Moreover, it is essential that incumbent firms assess their current competence base, identify competence needs, and act accordingly to reduce competence gaps to succeed in their digital transformation (Hess et al., 2016; Prezioso et al., 2020). Different approaches to ensure and develop the relevant competencies have been explored in the literature (e.g., Cordes & Rosemann, 2020), and in particular, appropriate training and culture are pointed out as essential to enable development of competencies relevant for digital transformation, which I elaborate on further in Section 3.4.

3.2 Employee reactions to digital transformation

Just as digital transformation may affect employees differently, employees may also react to the digital transformation in different ways. The second research stream focuses on different aspects of employee reactions to digital transformation. In particular, the widely studied topic of digital technology adoption, as well as employees' motivation for and attitudes towards digital transformation in general, fall into this category.

Digital technology adoption

Because digital transformation implies integration of digital technology, it is not surprising that digital technology adoption has been emphasized in the digital transformation literature. Technology adoption and related concepts such as technology acceptance and diffusion have been explored to understand the "human dynamics by which new artifacts become (or fail to become) embedded in the social and business processes of organizations" (Stam & Stanton, 2010, p. 24). The most prominent model applied to study digital technology adoption is the technology acceptance model (TAM), originally developed by Davis (1989). According to the TAM, employees' adoption of technology depends on their attitudes and intentions, which is driven by their perceived usefulness and perceived ease of use of the technology

(Davis et al., 1989). Employee attitudes' influence on digital technology acceptance has been subject to IS research for some time. Since the original TAM model, several other theories and models have been developed to increase our understanding of how and why technology and IS are adopted (or not), including the unified theory of acceptance and use of technology (UTAUT) model of Venkatesh and colleagues (2003) and other corresponding theories. Accordingly, a large body of IS research has investigated why employees resist or only partially adopt new IS—what Riemer and Johnston (2014) referred to as the "messiness" of IS adoption. Laumer and colleagues (2016) provided a useful overview of reasons for employees not adopting (i.e., resisting) new technology, indicating that the source of resistance may be the technology itself, the accompanying change, individual conditions, or perceived effects on work routines.

Moreover, the literature has emphasized that IS resistance may be psychologically driven (Laumer et al., 2016), often referred to as *negative psychology inertia* (Besson & Rowe, 2012), and that employees' emotions (Stam & Stanton, 2010) and beliefs (Solberg et al., 2020) can impact if and when employees adopt new digital technology. Accordingly, IS researchers have explored approaches for organizations to influence emotions and beliefs to enhance adoption. For instance, Kissmer and colleagues (2018) studied how digital *nudging* (i.e., use of design, information, and interaction to guide user behavior; Meske & Potthoff, 2017) can increase digital technology adoption. The authors argued that because of increasing complexity in the digital technology landscape following digital transformation, employees need more guidance to navigate through digital tools, and proposed digital nudging as a promising approach to support digital technology adoption and application (Kissmer et al., 2018). In a similar vein, Zimmer and Niemimaa (2019) found that the creation of a "digital compass" facilitated digital technology adoption by articulating potential digital technology affordances and helping employees navigate the complex digital landscape in the firm (Zimmer & Niemimaa, 2019).

Accordingly, organizations can employ different measures to increase employees' digital technology adoption in their digital transformation. Employee training (Ivančić et al., 2019; Riemer & Johnston, 2014) and appropriate organizational culture (Grotherr et al., 2019; Meske et al., 2018) have particularly been emphasized as factors influencing adoption. I discuss culture and training appropriate for digital transformation further in Section 3.4.

Employee motivation and attitudes

Employees' attitudes and motivation have also been investigated in the literature from a more general digital transformation perspective. In fact, digital transformation success largely depends on employees' attitudes towards it (Kensbock & Stöckmann, 2020) because attitudes influence the employees' intentions and willingness to actively support the transformation process (Meske & Junglas, 2020). Employees' attitudes and motivation towards the digital transformation can be both positive and negative—both of which will influence the digital transformation process and outcomes (Lichtenthaler, 2019).

The most common perspective in the IS literature portrays employees as mainly reluctant to or afraid of the changes related to digital transformation (Kensbock & Stöckmann, 2020) or even suffering from *technophobia* (i.e., "an irrational fear and/or anxiety that individuals form as a response to a new stimulus that comes in the form of a technology that modifies and/or changes the individual's normal or previous routine in performing a certain job/task," Khasawneh, 2018, p. 6). This perspective builds on assumptions that employees are generally reluctant to change (Armenakis & Fredenberger, 1997) and new technology (Aladwani, 2001; Markus, 1983). Digital transformation involves several and continuous changes in the organization and ways of working, which can be difficult for employees to cope with (Ivančić et al., 2019). If employees feel overwhelmed with the emerging technology and changes following the digital transformation, they may very well stick with the "old ways" of doing things (Mueller & Renken, 2017). If employees experience a feeling of their jobs being threatened by the digital transformation, they tend to "consciously or unconsciously resist the changes" (Tabrizi et al., 2019, p. 4). Moreover, if employees do not understand the need or aim of the digital transformation, they tend to have more reluctant attitudes towards the changes (Prezioso et al., 2020). Kensbock and Stöckmann (2020) further found that if employees expect that the digital transformation will lead to increased surveillance of their work, they will react more negatively to the transformation. Negative attitudes and limited motivation for digital transformation are found to be more apparent among older workers (Kluge et al., 2020; Prezioso et al., 2020).

On the other hand, research has also found that several employees exert positive attitudes towards and are motivated by the digital transformation. For instance, Kensbock and Stöckmann (2020) found that some employees saw the digital transformation as a learning opportunity, rather than a threat, which positively shaped their attitudes. Kluge and colleagues (2020) found that employees who felt confident in using digital technology, what is often referred to as *self-efficacy*, were more positive towards the digital transformation. This observation can be explained in that employees who perceive themselves as confident and holding appropriate competence in handling the digital technology introduced in the digital transformation also have positive expectations about their own performance and well-being following the transformation, which subsequently positively affects their attitudes towards the digital transformation (Meske, 2019; Meske & Junglas, 2020). Employees' self-efficacy is often explored as part of *self-determination*, which implies a perception of having confidence in their own competence (i.e., self-efficacy), autonomy in choice of actions, and relatedness with others (Meske, 2019; Meske & Junglas, 2020), all of which are found to positively influence employees' attitudes towards digital transformation. The positive relation between perceived or expected self-determination and attitudes towards digital transformation can be explained in that, if employees are stimulated and encouraged by the digital transformation to engage in a continuous learning process, they learn and adapt their behavior

(Kozanoglu & Abedin, 2020) and hence feel motivated to approach the changes following the transformation (Kensbock & Stöckmann, 2020). This motivation, in turn, makes these employees more willing to support and participate in the digital transformation (Meske & Junglas, 2020), for instance through offering relevant input during the process (Kensbock & Stöckmann, 2020) or even driving digital transformation initiatives (Mueller & Renken, 2017).

3.3 Employee engagement and involvement in digital transformation

The literature is clear in that employees play an important part in contributing to the success of an organization's digital transformation. Employees are both affected by and react to the transformation in different ways, and getting the employees on board—employee engagement—is essential for digital transformation success (Fitzgerald et al., 2014; Salviotti et al., 2019; Westerman, 2016; Winasis et al., 2020). Against this backdrop, the third research stream identified emphasizes the importance of employee engagement and approaches to involve the employees in the digital transformation process.

Bygstad and colleagues (2017) found that deep employee engagement contributed to the success of the digital transformation by enabling a digital transformation process focusing on finding solutions, rather than conflicts, and laying the ground for employee commitment and knowledge-sharing (Bygstad et al., 2017). Through engaging employees in the digital transformation, firms can leverage valuable knowledge possessed by employees, such as knowledge of organizational processes and customer demands, as well as knowledge of how colleagues perceive new digital technology and organizational changes (Garmann-Johnsen et al., 2018). Despite the general agreement on the importance of employee engagement during digital transformation, achieving engagement is found to be one of the top challenges of those leading the transformation (Kotter, 1995; Solis, 2019).

According to Kane and colleagues (2015), two factors are particularly important to achieve employee engagement: appropriate culture (Hemerling et al., 2018) and leadership (both of which are elaborated on more in Section 3.4), where communication plays an important part, for instance through storytelling (Kane et al., 2015) and management sharing relevant content regarding the digital transformation (Balakrishnan & Das, 2020). Moreover, from previous studies we have learned that limited employee focus and involvement are common reasons for IT implementation failure (Marchand & Peppard, 2008; Markus, 2004). Hence, researchers have suggested to actively involve the employees in the digital transformation process, which could also increase employee engagement (Mueller & Renken, 2017; Petrikina et al., 2017). In fact, Mueller and Renken (2017) posited that organizations should enable employees to join or even drive the digital transformation, facilitating employees to take on roles as the "company's true digital transformers" (Mueller & Renken, 2017, p. 2). This implies involving the employees in digital transformation initiatives and decisions, through, for instance, co-creation (Garmann-Johnsen et al., 2018; Mueller & Renken, 2017; Sommer, 2019), intrapreneurship (Reibenspiess et al., 2020), or internal crowdsourcing (Grotherr et al., 2019). In the context of healthcare organizations, Garmann-Johnsen and colleagues (2018) proposed that involving employees through co-creation of innovations would increase the knowledge base underlying the innovations and hence result in innovations that are better adapted to real life processes, and in turn, increased support and engagement from employees. In a similar vein, Mueller and Renken (2017) found that involving employees through co-creation stimulated the innovation potential held by the employees, triggering a cultural change enabling employees to see digital transformation initiatives as a facilitator to rethink ways of working.

3.4 Enabling factors

As the preceding sections indicate, the literature emphasizes three overarching themes that should be in place for organizations to engage the employees and take them into rightful consideration in their digital transformation, which I refer to as *enabling factors*. These include establishing appropriate culture, leadership, and training.

Culture

Creating an appropriate and supportive culture is found to be essential for achieving successful digital transformation (Ferreira et al., 2017; Fitzgerald et al., 2014; Hartl & Hess, 2017; Kozanoglu & Abedin, 2020; Mueller & Renken, 2017). A cultural shift is often necessary (Singh & Hess, 2017); however, adapting the culture is difficult (Kozanoglu & Abedin, 2020; Pan et al., 2008) as the existing culture and "traditional way of doing business is deeply entrenched in managers and employees" (Singh & Hess, 2017, p. 10). Organizations are encouraged to foster a culture that supports and tolerates the transformational changes and simultaneously enables the overarching strategy (Hemerling et al., 2018). Some researchers use the term *digital culture* (e.g., Ivančić et al., 2019; Kane et al., 2016) to denote the appropriate culture for digital transformation. Independent of the terminology, building and nourishing an appropriate culture is found to be important for digital transformation success (Osmundsen et al., 2018a) because it will help employees navigate the continuous changes following the transformation (Eden et al., 2019; Kozanoglu & Abedin, 2020) and stimulate their willingness to change (Cordes & Rosemann, 2020). Culture is also found to influence digital technology adoption (Meske et al., 2018). Further, research has found that an appropriate culture is important to attract and retain relevant talent (Gilch & Sieweke, 2020; Kane et al., 2015), which is particularly important considering the ongoing "war of talent" (Kluge et al., 2020). Without a digital culture, digital talent will not want to remain in the firm (Lee et al., 2017). One could also argue that a digital culture is both a necessary ingredient for successful digital transformation as well as a result of the transformation itself (Kane et al., 2015; Mueller & Renken, 2017).

Hartl and Hess (2017) identified openness to change, customer centricity, innovation (Reibenspiess et al., 2020; Solis, 2019), agility (Tabrizi et al., 2019), trust, and risk affinity (Kane et al., 2015) as cultural values crucial for digital transformation success (Hartl & Hess, 2017). Moreover, researchers have emphasized that firms should adopt a culture that stimulates collaboration (Ferreira et al., 2017; Tripathy, 2019), where mistakes are tolerated, and knowledge and information are shared (Hartl & Hess, 2017), helping managers inspire (Singh & Hess, 2017) and empower (Solis, 2019; Sommer, 2019) employees to be proactive, independent, and take part in discussions and decisions (Hartl & Hess, 2017). Further, the culture should stimulate continuous learning and training (Cordes & Rosemann, 2020; Ferreira et al., 2017; Hartl & Hess, 2017; Kensbock & Stöckmann, 2020).

Leadership

Digital transformation introduces new demands for leadership (Peter et al., 2020; Vial, 2019), and at the same time, appropriate leadership is found as a necessary prerequisite for digital transformation success. In particular, three aspects are emphasized in the literature. First, digital transformation is posited to change the way leadership should be exerted (Schwarzmüller et al., 2018; Tripathy, 2019). Different terminologies have been used to describe leadership during digital transformation, including terms such as *e-leadership* (e.g., Schwarzmüller et al., 2018), *digital leadership* (e.g., Tripathy, 2019), and *leadership 4.0* (e.g., Foerster-Metz et al., 2018). Independent of the terminology, digital transformation is suggested to require a leadership style that acknowledges and accepts the digital era; one that enables appropriate and passionate actions to be taken, characterized by creativity, accountability, and exploration (Tripathy, 2019). Dery and colleagues (2017) posited a *responsive leadership* style during digital transformation—where managers focus on how employees experience the transformation, are open to input and initiatives from employees, and encourage feedback. Schwarzmüller and colleagues (2018) argue for a *relationship-oriented leadership* style to support the employees in meeting and coping with the changes following the digital transformation. This involves taking into consideration the needs and wishes of the employees, as well as exerting leadership behavior characterized by coaching, networking, and teambuilding (Schwarzmüller et al., 2018). Moreover, a *transformational leadership* style is particularly emphasized as appropriate for digital transformation (Alos-Simo et al., 2017; Bygstad et al., 2017; Peter et al., 2020). Transformational leadership involves *transforming* employees' aspirations, attitudes, and values (Alos-Simo et al., 2017) and is, according to the original description in Bass and Avolio (1994), shown when leaders "stimulate interest among colleagues and followers to view their work from new perspectives, generate awareness of the mission or vision of the team and organization, develop colleagues and followers to higher levels of ability and potential, and motivate colleagues and followers to look beyond their own interests towards those that will benefit the group" (Bass & Avolio, 1994, p. 2). As such, transformational leadership style involves the leader inspiring employees (von Ohain, 2019) through their understanding of and identification with the leader (Alos-Simo et al., 2017). Transformational leadership is argued to be appropriate for digital transformation because it involves heavy collaboration between managers and employees, stimulates knowledge-sharing and innovative behavior (Peter et al., 2020), helps build a digital culture, and motivates continuous competence development (Alos-Simo et al., 2017).

Second, leaders are found to need a new set of attributes and skills to lead the digital transformation (Kane et al., 2015; von Ohain, 2019). Hence, the need for new competencies and continuous learning among employees is also stressed for managers (Schwarzmüller et al., 2018). Leading by example, managers should also develop relevant digital skills (Kane et al., 2015), and as Schwarzmüller and colleagues (2018) succinctly put it: "as employees need to be agile and creative and have to constantly change and develop themselves, leaders might likewise have to more actively promote and allow for such changes (e.g., by establishing a climate for change and reducing barriers) and learn more themselves to provide direction and optimal support for their employees" (p. 127). The authors found managers' abilities to inspire employees (Kane et al., 2015), handle and initiate change, and tolerate ambiguity, uncertainty, and complexity, as crucial for digital transformation (Schwarzmüller et al., 2018). Von Ohain (2019) identified *empathetic* (i.e., trustworthy, enthusiastic, respectful, coaching, motivating, and communicative) as the most important leader attribute for successful digital transformation, followed by attributes such as *innovative* (i.e., technology-oriented, customer-oriented, visionary, risk-taking), *open* (i.e., transparent, curious), and *agile* (i.e., fast) (von Ohain, 2019).

Third, digital transformation has led to an emergence of new leader roles, such as the *chief digital officer* (CDO) (Danilova, 2018; Singh et al., 2020). The CDO role may have emerged from a lack of other executive roles in the organization holding both a business and IS perspective (Danilova, 2018) in addition to the leader attributes mentioned above. The CDO is often set to lead the digital transformation in the organization (Haffke et al., 2016; Singh et al., 2020; Singh & Hess, 2017) and may take on different roles and approaches in doing so, depending on the needs and maturity of the organization, as well as the capabilities of the CDO (Singh & Hess, 2017). Nonetheless, the CDO should pay attention to employee needs and challenges. As Singh and Hess (2017) point out, "with the skill to inspire others CDOs not only act as consultants to the top management team, but also act as effective motivators of the whole workforce and thus enable the digital transformation in the first place" (p. 12).

Training

Employee training is seen as crucial for digital transformation success, not only because of the new competency requirements (Cordes & Rosemann, 2020; Sousa & Rocha, 2019), but also to help employees cope with the changes following the digital transformation (Singh & Hess, 2017), for instance through helping the employees develop "agility, flexibility, ability to make informed decisions and to respond promptly to change" (Prezioso et al., 2020, p. 9). Training should not be considered as a single activity during the digital transformation. Rather, training should be considered a key (Balakrishnan & Das, 2020) and constant (Ivančić et al., 2019) activity during the digital transformation. The literature emphasizes the importance of life-long learning (Ferreira et al., 2017) for the employees to keep up with the rapid advancements in technology development and avoid their skills becoming outdated (Foerster-Metz et al., 2018). Thus, organizations are recommended to offer employees opportunities to upskill, reskill, and maintain their skills on a continuous basis throughout their working engagement (Grundke et al., 2018; Prezioso et al., 2020).

Digital transformation may also induce new forms and improved methods for employee training. Foerster-Metz and colleagues (2018) suggest digital learning platforms to tailor training programs, where employees "can attend the training in alignment with their work schedules, matched with their self-pacing and choice of topic" (Foerster-Metz et al., 2018, p. 8). Ferreira and colleagues (2017) suggest the use of social media tools in training activities within different learning contexts, enabling flexibility in training modes. This is in line with Sousa and Rocha (2019), who found that the most prominent methods of learning in the digital era were collaborative communities, cooperative learning, and network participation. The authors also found that these digital learning methods were mainly exerted through mobile technologies and social media applications (Sousa & Rocha, 2019).

As training is considered a centerpiece for employee engagement and digital transformation success, the role of human resources (HR) and recruitment also becomes indispensable (Gilch & Sieweke, 2020). The role of human resource management (HRM) is found to change in the digital era (Fenech et al., 2019), where HR has an opportunity to directly and indirectly impact the digital transformation (Rimon, 2017) and ensure that the organizations "attract, retain and reap value from top millennial talent and thereby stay ahead of the competition" (Larkin, 2017, p. 59).

3.5 Summarizing remarks

Table 1 includes a summary of the identified research streams on the employee dimension of digital transformation, including prominent topics and example sources within each stream.

Table 1. Summary of identified research streams: Employee dimension of digital transformation

Research stream	Research topics	Example sources
1: **Impacts** of DT on employees	Impacts on work design/workplace	Foerster-Metz et al. (2018), Kluge et al. (2020), Meske & Junglas (2020)
	Emotional impacts	Ayyagari et al. (2011), Kluge et al. (2020), Stam & Stanton (2010)
	Impacts on jobs/labor market	Dengler & Matthes (2018), Frey & Osborne (2017)
	Impacts on competency requirements	Butschan et al. (2019), van Laar et al (2017, 2019)
2: Employee **reactions** to DT	Digital technology adoption	Kissmer et al. (2018), Laumer et al. (2016), Zimmer & Niemimaa (2019)
	Employee motivation and attitudes	Kennsbock & Stöckmann (2020), Meske & Junglas (2020), Kluge et al. (2020)
3: **Engaging and involving** employees in DT		Bygstad et al. (2017), Garmann-Johnsen et al. (2018), Grotherr et al. (2019), Mueller & Renken (2017), Reibenspiess et al. (2020)
4: **Enabling** factors	Culture	Hartl & Hess (2017), Kane et al (2015)
	Leadership	Alos-Simo et al. (2017), Schwarzmüller et al. (2018), Singh et al. (2020), von Ohain (2019)
	Training	Ferreira et al (2017), Foerster-Metz et al. (2018)

As the overview and discussions above illustrate, IS researchers have provided valuable contributions on different aspects of the employee dimension of digital transformation; however, many of these contributions are conceptual or only investigate parts of the digital transformation or some aspects of the employee dimension during digital transformation. Hence, there is need for more empirical evidence on digital transformation taking the employees into account. Furthermore, some of the insights derived from the contributions referred to above do not address incumbent firms directly, while digital transformation is different, and often more challenging for incumbent firms (Sebastian et al., 2017; Svahn et al., 2017; Warner & Wäger, 2019). This regards the employee dimension in particular, because established behaviors, technologies, and physical structures may constrain employees from accomplishing what the company needs them to in the digital era (Dery et al., 2017).

The insights derived from the literature emphasize that employees are subject to being heavily affected by the digital transformation and can deeply influence the direction and success of the transformation. To reduce the negative effects, boost the positive effects, and engage the employees to achieve digital transformation, incumbent firms should involve their employees in the digital transformation process and initiatives. With this thesis, I aim at further delineating the employee dimension of digital transformation in incumbent firms to explore how incumbent firms should involve their employees in the transformation, and thereby contribute to prevailing IS research and digital transformation literature.

In the first article, we add to the first research stream, exploring which competencies are essential for incumbent firms in their digital transformation, and how such competencies could be obtained. In the second article, we add to the third research stream, addressing how employees and other organizational actors interact during a continuous development approach to digitalization as part of the larger digital transformation. In the third article, we add to the second research stream by expanding theory to understand how and why employees understand complex digital artifacts in the context of digital transformation in incumbent firms. In the fourth article, we do not have a primary focus on employees; however, we address the development of a complex digital artifact through co-creation between a digital company and an incumbent firm as part of the digital transformation of the latter, where the employees played a central part in this co-creation. Thereby, we indirectly contribute to the third research stream and employee involvement.

4. Methodological choices

With this research, I aim at contributing to the IS field and the conversation on digital transformation. The mission of the IS discipline is to theorize and explore the role of "digital" for individuals, organizations, and society (Markus & Nan, 2020), and a common focus of IS researchers is to investigate managerial and organizational issues (Myers, 1997) associated with digital technology. Hence, as IS researchers, we do not merely study technical aspects of digital technology. Rather, we examine socio-technical systems; in other words, both the social and technical aspects of digital technologies in interaction, intersecting "knowledge of the properties of physical aspects (machines) and knowledge of human behavior" (Gregor, 2006, p. 613).

This thesis consists of four individual and interrelated empirical research articles, all of which are based on a longitudinal case study at an incumbent firm in Norway. As each individual article includes a detailed presentation of methodological approaches, I have tried to keep this section short, emphasizing important methodological choices and adding complementary aspects that were left out of the articles due to length restrictions. In the following subsections, I discuss the philosophical assumptions underlying my research before I present the chosen research method, case setting, and how I approached data collection, treatment, and analysis.

4.1 Research paradigm

Research paradigms relate to a set of philosophical assumptions about the world guiding researchers in their selections of tools, instruments, participants, and methods (Ponterotto, 2005). The research paradigm represents the researchers' beliefs regarding ontological (e.g., the nature of reality and being) and epistemological questions (e.g., how knowledge is constructed) (Creswell, 2012; Ponterotto, 2005). In my research, I have adopted an interpretive epistemology, which assumes that knowledge is created intersubjectively (Thapa & Hajboluri, 2020) and that inferences or knowledge claims about reality are made through observing events. By adopting an interpretive epistemological perspective, I acknowledge that I as a researcher may have influence on what I am studying. I also assume a non-dualist view, in that I perceive technology and social constructs as intertwined and influencing each other (Thapa & Hajboluri, 2020).

Regarding ontological beliefs, I did not take any particular stance in conducting my research; however, in hindsight I consider a critical realist ontology to perhaps be most aligned with my overall research approach and objectives (Sandberg, 2014). Ontologically, critical realism assumes that there exists one true, objective reality (e.g., realist ontology), but also that this reality is only imperfectly apprehendable and measurable (Ponterotto, 2005). This position comes from the perspective that humans are flawed (Guba & Lincoln, 1994) and that human knowledge only captures parts of a vaster reality (Fletcher, 2017). In other words, critical realism depicts that ontology is not dependent on epistemology; things can exist that we might not have knowledge about (Fletcher, 2017; Øgland, 2017).

I built on initial theories as foundations in my research, acknowledging that my analyses and findings might support, elaborate, or deny the initial theoretical propositions (Fletcher, 2017). When collecting data, I acknowledged that interview respondents perceive different meanings, in line with the interpretivist view, and in analyzing the data I sought to comprehend these collective meanings into an approximate reality, which is in line with the critical realist view (Ponterotto, 2005). Accordingly, based on qualitative data comprehending collective meanings collected from several sources, I sought to identify an approximal reality in the data and generate knowledge claims (Bygstad et al., 2016) through, for instance, rigid strategies for data analysis and collaboration with co-authors.

4.2 Research method

I chose a qualitative research approach, which I find suitable for studying emergent phenomena such as digital transformation. Qualitative approaches are common to interpretivism and critical realism and have been extensively applied within the IS field (Ivančić et al., 2019; Myers, 1997). A qualitative approach allows me to investigate and understand phenomena from the point of view of the participants and in their social and institutional context (Kaplan & Maxwell, 2005) and incorporate participants' own words to describe events or experiences (Ponterotto, 2005). To capture the essence of digital transformation, I chose a longitudinal case study design. A case study involves studying a case within a real-life, contemporary context over time through detailed, in-depth data collection from multiple sources (Creswell, 2012) and is acknowledged as particularly appropriate for topics in which research and theory are at their early stages (Benbasat et al., 1987) and where the aim of the study is to understand complex social phenomena within a context (Yin, 2014). The research was longitudinal (Pettigrew, 1990) in that I followed a case organization over time, from September 2018 to July 2020. During that period, I spent one to three days a week with the company, and I continued to keep in touch and nurture relationships with contact persons in the case organization after my stay. Rich access to the case organization over time enabled me to develop a deep understanding of the organization and their digital transformation, explore and interpret ongoing digitalization processes within the organization's context, and take the employee dimension into consideration.

4.3 Case setting

The case organization, referred to as "GridCo", is a large Norwegian grid company. Like all grid companies in Norway, GridCo is responsible for building, operating, and maintaining the regional and local grid network within a specific geographic area, and thus, for providing electricity to customers—both private households and industry actors. I chose this company as a relevant case organization because of its characteristics as an incumbent firm (Chanias et al., 2019; Engesmo & Panteli, 2020; Sebastian et al., 2017) and the company's ambitions of digital transformation. The company has a long legacy of providing electricity to a large customer base in Norway since the early 1900s and it is a rather large company (in the Norwegian context), with over 500 employees and more than 240,000 customers. Because of how the grid sector is set up in Norway, GridCo, as other Norwegian grid companies, holds a monopolistic position in distributing electricity to customers within their geographical area. This position has over time led to long traditions in the way the company is managed and organized, the business model, and ways of working.

However, more recently, trends within sustainability and digital technology are challenging grid companies and the energy sector in general. The entire energy system is changing, where trends such as electrification, self-generation, and local energy solutions have led to new ways to produce, distribute, store, and consume energy. Further, an increasing number of digital elements and smart components, such as automated meter reading (AMR), are being incorporated in all layers of the energy network (Kettunen & Mäkitalo, 2019) in Norway. With AMR technology, grid companies can collect accurate and (almost) real-time data for energy consumption, which, combined with other data sources, can provide grid companies with a richer and more accurate foundation for improving services and satisfying customers. At the same time, new competitors are entering the field—ranging from larger enterprises, non-industry entrants, and smaller startup companies. Norwegian regulatory actors are introducing (or planning to introduce) new regulations and guidelines that may stir up the dynamics in the industry, leading the major companies towards more cooperation, changed roles, new business models, and new ways to approach the end users. Moreover, the development in the industry is happening at a much faster pace than earlier development, and hence, actors in the industry need to transform to stay relevant and competitive. Accordingly, GridCo is engaged and invested in several digitalization efforts, and as they have also expressed themselves; they are in the midst of a digital transformation. In the four articles included in this thesis, I address different aspects of GridCo's digital transformation and accompanying digitalization efforts. In the following subsections, I present how I collected, treated, and analyzed data.

4.4 Data collection

GridCo was helpful and open in providing access to their organization and accommodating my needs and interests as a researcher. After spending a couple of months getting to know the company and talking to several employees and managers, I approached the top management team of GridCo and presented my intended research topics and approach to data collection. Having the top management's cooperation was essential. First, they provided necessary access to the organization, including physical locations and relevant information systems. Second, they introduced my research agenda to employees, which eased the process of meeting potential respondents and scheduling interviews. Third, with the management's cooperation and awareness of my research focus, it was easier for them to include me in situations they might consider relevant for my research. While engaging with the case company, I gathered data from three sources: interviews, observations, and archival data, with interviews being the main data source.

Interviews

To get access to relevant interview respondents, I approached the head of administration at GridCo to get his point of view on whom I could interview. He pointed me in the direction of relevant departments in the company. Having introduced myself to the department heads and informing them of my research project, I asked for their permission to interview them and some of their employees. They were positive and open, and included me in some of their department meetings to introduce me to their employees. This was important to me, as I wanted to meet potential interview respondents face-to-face prior to sending them an interview invitation. This was both because I believe it is common courtesy to introduce oneself prior to sending an impersonal calendar-invitation, and also to briefly explain to them the research project and the intention of the interview so that they could make an informed choice regarding their participation. Although this process was rather time-consuming, I believe it was necessary to ensure appropriate treatment of the respondents. Interviews where only scheduled with persons who had agreed to participation a priori.

In total, I conducted 55 interviews with 49 respondents; 47 respondents from GridCo and 2 respondents from an external collaboration partner, DigitalCo (see Articles 3 and 4 for more information on DigitalCo). Each interview lasted between 30 minutes and two hours and was recorded (with the respondents' consent) and transcribed verbatim. In total, the interviews generated more than 600 written pages of transcripts. I chose a semi-structured format for the interviews, using interview guides as a basis and supplementing with additional questions when necessary. In the interviews I focused on achieving an open conversation, engaging in active and non-judgmental listening (Walsham, 1995), and taking into account several of the techniques recommended by Seidman (2013), such as asking real questions, following up on the respondents' answers, not interrupting, asking for concrete details, and asking the informants to tell stories to elaborate on certain topics. In addition to the scheduled interviews, I had several informal conversations and meetings with employees and managers in the company. Table 2 presents an overview of the interviews conducted.

Table 2. Overview of interviews

	2018		2019		2020	
	# Interviews	Duration	# Interviews	Duration	# Interviews	Duration
GridCo Operational-level employee	3	174 mins/ 2.9 hours	25	1158 mins/ 19.3 hours	4	256 mins/ 4.3 hours
GridCo Middle manager	6	317 mins/ 5.3 hours	8	554 mins/ 9.2 hours	2	121 mins/ 2.0 hours
GridCo Top management	1	55 mins/ 0.9 hours	3	161 mins/ 2.7 hours	1	67 mins/ 1.1 hours
DigitalCo Representative	-	-	-	-	2	126 mins/ 2.1 hours
Total 55 interviews: 2,989 mins/49.8 hours	**10**	**546 mins/ 9.1 hours**	**36**	**1873 mins/ 31.2 hours**	**9**	**570 mins/ 9.5 hours**

In the first round of interviews, in 2018, the aim was to gain insight and understanding of the case organization and its digital transformation. In this round, I interviewed both managers at top and middle levels and operational employees. The interview guides were particularly broad and open to ensure I could capture what the interview respondents considered as challenging or important regarding GridCo's digital transformation. These first interviews also informed my choice of topics for the articles in this thesis, and hence shaped the content and focus of the interviews in the subsequent rounds. In 2019, I continued to conduct some of these broader interviews to lay the grounds for my research; however, based on the initial interviews I had started to develop ideas regarding topics of interest to investigate further, including employee competencies (Article 1) and looking further into the digitalization efforts related to OPRA (Article 2) and the digital twin of the grid network (Articles 3 and 4). Hence, while interviewing both employees and managers (top and middle), the conversation was somewhat more focused on these topics, although still also considering the overall digital transformation of GridCo. The third round of interviews in 2020 served mainly for supplementing the data with additional interviews where I needed clarifications or more information to explore specific research topics, in particular regarding the digital twin.

Although I did not collect sensitive information during the interviews, respondents might have shared perspectives and opinions that they otherwise would not want to share with their managers or coworkers (or outsiders such as myself). Thus, I found it important to ensure anonymity and confidentiality when conducting the interviews and treating the data (Fujii, 2012). All potential interview respondents received an information letter prior to an interview invitation, stating among other things the purpose of the research, measures for how confidentiality would be accommodated, and the participant's rights to withdraw consent (The Norwegian National Research Ethics Commitees, 2016). The letter was produced according to guidelines of Norwegian Centre for Research Data (NSD) and approved by NSD. Further, I adhered to interviewing guidelines and techniques (e.g., Seidman, 2013) to ensure an open and safe interview session where the respondents would not feel tricked, manipulated, or forced into saying something they did not want to or did not mean, and to treat the respondents with respect and without judgement. Audio recordings of interviews were deleted after the interviews were transcribed. Transcripts were anonymized and stored safely—separately from the overview of interview respondents. An overview of all interviewees was safely stored in a protected Excel workbook, to which only I had access and knew the password.

Observations

Observations were another important source of data. By spending one to three days a week with the case organization for almost two years, I was able to conduct rich observations through physically sharing work locations with employees, overseeing discussions, participating in lunch-talks, and attending several meetings, including department meetings, project meetings, management meetings, and staff meetings. This enabled me to view the organization from an insider perspective (Jorgensen, 1989). Observations were documented in field notes (approximately 100 pages) and pictures (not of persons or sensitive information), which were also stored safely where only I had access, and constituted a valuable data source and foundation for data analysis and further data collection. I chose an outside observer role (Walsham, 1995), with some (albeit limited) degree of participation (Jorgensen, 1989). I was not a pure outside observer but was to some degree treated as a temporary employee by parts of the organization, and I did participate in meetings; however, I did so with the intention to oversee, rather than contribute to, discussions. To manage my proximity to the case organization (Fujii, 2012) and ensure I did not interfere too much with the context under study when conducting observations (Jorgensen, 1989), I focused on being open with the employees about the intentions and reasoning behind my presence, and treated my presence at GridCo as strictly professional and research-focused.

Archival data

My research also included extensive amounts of archival data, which were accessed through the case organization's document archive system, collaboration platforms, and other information systems. This included strategy documents, project plans, presentations, and budgets, and a significant number of postings and news on their internal communication platform. Archival data served as a valuable foundation and complementary information to better understand the case organization, their digital transformation, and specific digitalization efforts. Documents and archival data gathered from the case organization were stored on a separate computer; a computer belonging to the case organization purchased for the purpose of my research project. As such, the documents remained safe within the case organization. Access to the case organization's information systems was also only available through this computer.

4.5 Data treatment

When conducting qualitative research, it is important to obtain voluntary, informed consent to collect data from participants (Fujii, 2012; Seidman, 2013; The Norwegian National Research Ethics Commitees, 2016). Regarding interviews, voluntary, informed consent was ensured by informing potential respondents of the intentions of the research and interview, their rights, and that participation was voluntary. Consent to record interviews was obtained verbally in the beginning of each interview. I also assured them that the recordings would be deleted immediately after the interviews were transcribed, and that the participants were de-identified in the transcripts and articles. This was all written down in the information letter (NSD) they received prior to the interviews. To ensure voluntary, informed consent when conducting observations, I followed some predefined principles. First, I only audio-recorded interviews and only if the interview respondent consented. Hence, I did not audio-record meetings or other conversations. Second, I only took notes during meetings or conversations if it was appropriate. In informal settings, such as lunch-talks, taking notes was considered inappropriate. Third, I was open with the employees around me about what I was working on to ensure they understood that I only took field notes of what was of relevance for my research (and that I did not register if they came in late, left early, had a bad day, etc.). Fourth, I explained to the employees that an important part of my observations and presence was to capture the culture and essence of the organization. It was not only about taking notes and participating in meetings, but also to understand the organization from an insider perspective.

The research project was reported to NSD. The report to NSD included information on types of data I was to collect, the purpose and duration of the research project, and who would have access to the data collected. The report also included general information about the sample, and how data would be collected, documented, and treated. All data were treated and stored according to NSD guidelines and documented in an information letter distributed to interview participants, the NSD report, and a confidentiality agreement I signed with the case organization. All data were securely stored, inaccessible to others, and are only stored for the duration of my research project.

In addition, I was particularly cautious in treating some of the data collected and information I was presented, as the Norwegian energy sector is subject to regulations of the "Energy Act"[3] and "The Regulation on Security and Preparedness in the Energy Supply."[4] According to these regulations, data about, for instance, the grid network configuration and setup is regarded as sensitive power system information, and thus cannot be shared with outsiders. Accordingly, I attended a course in power sensitivity and maintained close dialogues with contact persons at GridCo to clarify the degree of sensitivity of data and what I could and could not include of information in the articles.

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[3] "Energiloven": https://lovdata.no/dokument/NL/lov/1990-06-29-50

[4] "Kraftberedskapsforskriften": https://lovdata.no/dokument/SF/forskrift/2012-12-07-1157

4.6 Data analysis

Data collected from the case organization (interviews, observations, and archival data) served as data sources for all four articles. However, although the overall focus of my research was the digital transformation of GridCo, in each individual article we focused on different aspects of their digital transformation. Accordingly, interviews and observations conducted, as well as documents collected, aimed at capturing different aspects of the digital transformation relevant for my research. This implies that while some interviews aimed at uncovering the digital transformation in GridCo in general served as a basis for all articles, other interviews aimed at capturing the essence of specific digitalization initiatives as part of the digital transformation and were only included as data sources for individual articles.

In Article 1, we wanted to investigate the competence-related aspects of digital transformation at GridCo to capture which competencies are essential for incumbent firms in their digital transformation and how these could be obtained. Accordingly, relevant documents such as competence plans, strategies, and employee registers were studied in detail, and interview transcripts and field notes were analyzed in terms of competence-related elements. To analyze the data, we applied a theoretical thematic analysis (Braun & Clarke, 2006) driven by our research objectives. Following six steps, inspired by Braun and Clarke (2006), we first familiarized ourselves with the data and tried to capture the story of competence development in GridCo in light of digital transformation. We then generated themes and coded data extracts according to their relevance to our research questions. Through developing a thematic map, we analyzed the themes and accompanying codes and data extracts to capture competences essential in GridCo's digital transformation. Further, based on our theoretical foundation and findings, we developed a generic model for obtaining digital transformation competencies.

In Article 2, we investigated a particular digitalization effort as part of GridCo's overall digital transformation, namely the evolution of the digital infrastructure connected to the system OPRA. We relied on the same data as underlying Article 1; however, we supplemented the data with two additional interviews and collected additional documents regarding the OPRA infrastructure and its development process. When analyzing data for this article we were inspired by the ladder of analytical abstraction (Carney, 1990; Miles et al., 2013) and approached the data analysis in three phases. Starting with the interview transcripts, field notes, and relevant documents, we used an open coding approach to familiarize ourselves with the data and understand the case organization and the OPRA infrastructure. Then, we approached the data again, this time coding the data based on our conceptualization of continuous development to understand how OPRA evolved through continuous development. Finally, we wanted to understand the interactions occurring between organizational actors during the continuous development in more detail. To do so, and based on the understanding developed in the first phases of data analysis, we found the notions of sense-making (Weick, 1995) and sense-giving (Gioia & Chittipeddi, 1991) as useful. We applied these ideas to better understand the interactions that occurred and how they fueled the continuous development of OPRA and to theorize our findings into an explanatory framework and generic model (Miles et al., 2013) of interaction patterns during continuous development.

In Article 3, we were interested in capturing the essence of a particular digital artifact developed as part of GridCo's digital transformation; a digital twin of the grid network. From the initial data that had already been collected, we were able to capture the main essence of the digital twin in the context of GridCo. After discussion among the authors, we identified affordance theory as a relevant theoretical perspective to study how employees at GridCo understood the action possibilities offered by the digital twin. However, while reviewing the IS literature on affordances, we identified a theoretical gap in the relational aspect of affordance perception and agreed that an integration of two specific concepts from the Heideggerian philosophy could contribute to reducing this gap. To accomplish this, however, we acknowledged that we needed to conduct additional interviews to capture the relation between the digital twin and the users of the digital twin (employees at GridCo) and how the users perceived digital twin affordances. Accordingly, we supplemented our data sources with additional interviews, conducted additional observations, and collected further archival data regarding the digital twin artifact and project.

With an objective of exploring how the Heideggerian concepts of "familiarity" and "referential totality" could help specify and increase our understanding of the relational aspect of affordance perception, our data analysis was guided by the literature on affordance theory and these Heideggerian concepts. As with the first article, we applied a thematic approach to data analysis, driven by our theoretical interests and inspired by the phases of thematic analysis presented by Braun and Clarke (2006). We coded the data according to themes regarding affordances, familiarity, and totality and analyzed the themes with an aim of both delineating the digital twin affordances perceived by the employees, as well as capturing a link between affordance perception and familiarity and totality from Heidegger's thinking. Based on our findings, we found that the employees perceived digital twin affordances when and because they were familiar with the digital twin totality. Building on these insights, we developed a theoretical model of the relational aspect of affordance perception by integrating the Heideggerian concepts of familiarity and totality.

In Article 4, we did not follow any specific pre-defined strategy for data analysis. Based on the insight gained from analyzing the data for Article 3, we found the aspect of co-creation as particularly relevant for a more practitioner-oriented audience; a topic that we did not address in the third article. Accordingly, we reread the data underlying Article 3, and chose an open-coding approach to capture relevant aspects of co-creation, the relation between GridCo and DigitalCo, and lessons that could be learned from this approach to digital twin development. In this article, we also wanted to provide the reader with more detail on the digital twin at GridCo, and accordingly, we also analyzed the data with an aim of capturing a more detailed presentation of the digital twin itself.

Qualitative data analysis should be conducted with openness, fairness, and self-criticism (The Norwegian National Research Ethics Commitees, 2016) because qualitative data can be subject to multiple realities and interpretations (Miles et al., 2013). Following this, I have focused on openness and transparency in analyzing data, explicitly describing how data analysis was conducted and how the analysis process evolved for each article. I have followed analytical methods and techniques that are established and recommended within the IS community. To ensure fairness, I have presented and discussed elements of the data analysis with contact persons in the case organization prior to submitting articles. In doing so, I have asked for their feedback on whether they believe the analysis fairly and adequately reflects the truth and the case of the organization. Finally, I have exerted self-criticism through relying on feedback from supervisors and peers from the research community and collaborating with prominent IS researchers through co-authorship.

4.7 Trustworthiness of findings

I applied the same qualitative case-study approach in all articles included in this thesis. To evaluate the trustworthiness of findings, I applied the criteria proposed by Lincoln and Guba (1985) for qualitative research: credibility, transferability, dependability, and confirmability.

Credibility concerns the findings' congruence with reality, which is influenced by the methodological choices underlying the findings (Lincoln & Guba, 1985). As described in the previous sections, rich data were collected and analyzed with rigor while at the same time ensuring the ethical and appropriate treatment of respondents. Through collaborating with co-authors and receiving feedback from peer scholars, the processes of data collection and analysis were reviewed and improved to enable credible findings. Moreover, credibility was ensured by *prolonged engagement* with the case organization, giving me sufficient time to capture the essence of GridCo's digital transformation; *persistent observation*, allowing me to identify and focus on relevant aspects of the digital transformation; and *triangulation*, relying on several data sources to capture the whole picture (Lincoln & Guba, 1985). In addition, models derived from the data collection and analysis were checked with GridCo respondents to ensure we had interpreted the data accurately, and in some cases drafts of articles were reviewed by contact persons at GridCo to validate the findings and to ensure compliance with the Energy Act.

Transferability refers to the findings' applicability to other contexts (Lincoln & Guba, 1985). The findings in the articles are based on a case study approach in the Norwegian grid sector, where both the Norwegian context and grid sector context may have their peculiarities. However, the findings are presented with transparency through providing rich descriptions of the case and context and rich information about the data collected, including examples of data extracts (i.e., quotes) (Lincoln & Guba, 1985). Our findings build on existing literature and strong theoretical foundations, and I believe that the way in which we conducted and reported our research allows for our theoretical propositions to be transferred or expanded to other contexts (Yin, 2014). Moreover, the way in which we have presented

GridCo's approach to digital transformation provides valuable learning for IS researchers and may serve as inspiration for other firms in other contexts.

Dependability can be considered the qualitative approach's substitution for reliability (i.e., that the findings can be replicated in new, similar studies), which is practically impossible to achieve as qualitative studies depend on context, and contexts are subject to change (Lincoln & Guba, 1985). Instead, as qualitative researchers, we should aim for dependability, in that our findings are consistent with the underlying data and that the research process is sufficiently documented for readers to be able to follow and critique. In this thesis, consistency was enhanced through collaborating with co-authors and keeping a close dialogue with the case organization. Furthermore, in reporting the research process to readers, each article provides detailed descriptions of how data were collected and analyzed.

Confirmability regards the characteristics and quality of the data (i.e., whether the data are confirmable; Lincoln & Guba, 1985). In this thesis, confirmability was in ensured through triangulation. Data collected through interviews were checked against observations and documentations, and vice versa. By being engaged with the case organization over time, I was also able to contact GridCo representatives at any time to clarify information retrieved from the data, and so they could elaborate where I needed more information. Moreover, by keeping a research journal and writing field notes throughout the research process, I was able to document the approach and capture potential discrepancies in the data.

5. Introduction of articles

In the following subsections, I briefly present the four articles included in this thesis. In each article we address important aspects and common challenges in the digital transformation of incumbent firms and consider the employees to play a central part in such transformation in different ways, either directly or indirectly.

5.1 Article 1: Digital transformation and the need for new competencies (Osmundsen & Iden)

In the first article, we addressed changes in employee competence requirements following digital transformation. Because digital transformation inherently implies integrating digital technologies and business processes (Liu et al., 2011), new competencies are required to adopt, master, and manage these new digital technologies (Butschan et al., 2019; Fitzgerald et al., 2014; Gupta et al., 2018; Mueller & Renken, 2017; Vial, 2019). However, there is limited research on which competencies are particularly relevant for incumbent firms in their digital transformation (Butschan et al., 2019; Shahlaei et al., 2017), and how these competencies could be obtained (Eden et al., 2019).

To reduce this gap, we explicitly collected and analyzed the data to explore whether and how employee competence requirements shifted at GridCo following their digital transformation. Our research questions were: *Which competencies are essential for digital transformation?* and *How can incumbent* *firms obtain digital transformation competencies?* Drawing on relevant IS literature on capabilities and competencies, we devised the concept *digital transformation competence,* identified competencies that may be considered essential for digital transformation in incumbent firms, and developed a generic model of approaches for incumbent firms to obtain digital transformation competencies.

This article contributes to both research and practice by unpacking the concept of digital transformation competence and, hence, increasing our common understanding of what digital transformation entails and how incumbent firms should embrace digital transformation. By doing so, we also emphasize ways in which employees are affected by digital transformation regarding new competence requirements. This article is currently under review at the journal *Information and Organization*.

5.2 Article 2: Making sense of continuous development of digital infrastructures (Osmundsen & Bygstad)

In the second article, we explored a specific digitalization effort as part of GridCo's larger digital transformation; the development of a digital infrastructure connected to the software OPRA. We observed that how this digital infrastructure (i.e., socio-technical network of technology and users, Hanseth & Lyytinen, 2010) evolved was not consistent with the established perspectives of digital infrastructure evolution. Rather, the evolution of the OPRA infrastructure had characteristics that corresponded with *continuous development*, an idea that has emerged from DevOps (an extension to Agile software development). Continuous development has been recommended to be explored in broader organizational contexts (Bussgang & Clemens, 2018); however, this has not been done before. Hence, the objective of this article was to theorize the idea of continuous development in the context of digital infrastructure evolution and explore the forces of the phenomenon.

By drawing on literature on digital infrastructure theory and continuous development as it has emerged as an idea from the DevOps thinking expanded from Agile, we outlined the main characteristics of continuous development and proposed a theoretical definition of continuous development in organizational contexts. We used this conceptualization to understand how the digital infrastructure connected to OPRA evolved through continuous development and found that dynamic interactions between actors at different organizational levels (including employees) fueled the continuous development. Then, in answering our research question *Which patterns of interactions can be identified in the continuous development of digital infrastructures?* we applied the ideas of sense-making (Weick, 1995) and sense-giving (Gioia & Chittipeddi, 1991) to understand and theorize these interactions in more detail. Based on our findings, we developed a generic model of interaction patterns with two cycles of sense-giving and sense-making between organizational actors enabling the continuous development of digital infrastructures.

Our findings and model of interaction patterns offer a nuanced perspective on both digital infrastructure evolution and the established perspectives of sense-making and sense-giving mechanisms, as well as new ways to think about digitalization in incumbent firms. Moreover, we shed light on the importance of and ways in which employees should be involved in digitalization efforts through dynamic interactions as part of the organization's larger digital transformation. This article is currently under review at the *Journal of Information Technology*.

5.3 Article 3: Familiarity with artifact totality: Exploring the relation and perception of digital twin affordances through a Heideggerian perspective (Osmundsen, Meske, & Thapa)

In the third article, which is perhaps more theoretical than the other articles, we drew insight from another specific digitalization effort as part of GridCo's digital transformation; the development of a digital twin of the grid network. Digital twins represent exact, digital replications of physical assets (Grieves, 2014) and are predicted as key components and possibly even drivers of firms' digital transformations (Saracco, 2019). However, the question of how increasingly complex digital artifacts, such as digital twins, are understood in the workplace is still unanswered. To explore how organizational actors understand and interact with digital technology, affordance theory (Gibson, 1986) has been extensively applied by IS researchers. Within the IS field, affordances are broadly viewed as possibilities of actions in the relation between an IT artifact and a goal-directed actor (Strong et al., 2014). However, existing perspectives on affordances fall short in providing details on the relational aspect of affordance perception. To increase granularity and specificity in this regard, IS researchers have suggested it be supplemented with other concepts. In this article, we argued that the Heideggerian concepts of "familiarity" and "referential totality" are well suited to this endeavor. Hence, the objective of this article was to *explore how the Heideggerian concepts of familiarity and referential totality help specify and increase our understanding of the relational aspects of affordance perception*.

To do so, we collected and analyzed the data to understand the relation between the users (employees at GridCo) and the digital twin and how the users understood the digital twin (i.e., which digital twin affordances they perceived and why). We found that users' familiarity with the artifact totality enabled them to perceive digital twin affordances, and that without this familiarity, the affordances remained latent for the users. Based on our findings, we developed a theoretical model of the relational aspect of affordance perception where we integrated the Heideggerian concepts of familiarity and referential totality.

With this article, we contribute to IS research in both specifying the relational aspect of perception in affordance theory, providing valuable insights into how digital twins are understood and applied in practice, as well as explaining the mechanisms that need to be in place for users to develop familiarity with the artifact totality. Moreover, we address how employees understand complex digital artifacts, such as digital twins, when introduced in incumbent firms' digital transformation, and which mechanisms can influence this understanding, and eventually the application of the artifact. This article is currently under review at the *Information Systems Journal*.

5.4 Article 4: Co-creating a digital twin for the energy sector (Meske, Osmundsen, & Junglas)

I have also included a fourth article in this thesis, in which we address the same digital twin as in the third article; however, we do so in a more practitioner-oriented manner. Where we in Article 3 focused on developing theory and did not have much room to elaborate on the rather spectacular case of a digital twin of the grid network; in this article we focused on bringing to light the practical applications and potential benefits of digital twin technology, specifically providing valuable insight into how digital twins can be developed through co-creation.

In this paper, building on insights from the data underlying Article 3, we illustrated how co-creation between GridCo and DigitalCo served as a prerequisite for the development of a digital twin of the grid network and point to lessons learned from this co-creation. Although we did not directly investigate the employee dimension of digital transformation in this article, we did so indirectly, as employees were important contributors in this co-creation. We highlighted how the co-creation and digital twin project led to a deep reflection on existing competencies, routines, and business models, which in turn uncovered crucial potential for innovation and repositioning in the market. Although not a typical academic research article, I have included this article in the thesis because I believe it supplements the third article nicely by showcasing the digital twin as a potentially important ingredient in incumbent firms' digital transformation and providing valuable contributions for practitioners. This article is currently under review at the journal *MISQ Executive*.

6. Discussion

When starting on my PhD, I did not set out to place any particular focus on employees during digital transformation; rather, this was something that emerged as important over time while engaging with the case organization and consulting with prevailing literature on digital transformation. Accordingly, when conducting my research, I did not intentionally aim to contribute to the digital transformation discourse by shedding light on the employee dimension; however, with the employee at the back of my mind while collecting and analyzing data and presenting the findings through writing the articles, I realized this valuable contribution in hindsight. This realization resulted in delving into the literature yet again, this time with an aim of uncovering what is known about the employees during and after digital transformation. The insight gained from this endeavor was presented in Section 3 of this thesis, which also informed the overarching research question and framing of this introductory chapter.

Accordingly, while each individual article has different objectives related to digital transformation in incumbent firms and is driven by independent research questions that do not necessarily concern the employee dimension, my research contributes to IS research and practice on two dimensions. First is through the overall contributions derived from my research and the four articles collectively in answering the overarching research question, which I discuss in Section 6.1. Second is that each individual article contributes to IS research and practice in its own specific way, beyond the employee dimension, which I discuss in Section 6.2.

6.1 Overall contributions

In this section, I return to the overarching research question of this thesis: *How should incumbent firms involve their employees in their digital transformation?* Through this introductory chapter and the four articles in this thesis I offer valuable insights that contribute to answering this research question, and in doing so, my research makes several contributions to IS research and the discourse on digital transformation.

First, as part of this introductory chapter I have reviewed and presented prominent IS literature on the topic of digital transformation, and thereby provided a thorough overview of what digital transformation means and entails for incumbent firms, drivers, facilitating conditions, and implications of digital transformation, and how this type of organizational transformation differs from traditional ITOT. Moreover, in each article included in this thesis I address different aspects of digital transformation in incumbent firms—where the topics were inspired by the literature and case organization, based on what is considered particularly challenging or important for incumbent firms in their digital transformation. Ranging from a holistic digital transformation perspective with a focus on competencies (Article 1), to specific digitalization efforts as part of incumbent firms' larger digital transformation (Article 2–4), the collective insights gained from my analyses, findings, and presentation of GridCo's digital transformation increases our understanding of digital transformation in incumbent firms.

Second, by reviewing relevant and recent IS literature as part of this introductory chapter, I provide structured insight into what researchers have found regarding the employee dimension of digital transformation. This insight stresses the relevance and importance of employee involvement for successful digital transformation. Digital transformation is found to deeply affect employees; however, the effects vary between employees, depending on, for instance, their work situation and perceptions of their own abilities. Digital transformation implies integration of several digital technologies, often in combination, which leads to changed work practices and the introduction of new positions. This may have emotional implications for employees, especially if the digital transformation requires them to take on changed roles or develop new competencies. Depending on how the changes following the digital transformation affect the employees, they react differently. Some are motivated by the digital transformation and embrace the new digital technologies with interest and curiosity. Others are more reluctant to the digital technologies and may have less positive attitudes towards the digital transformation. Nonetheless, research has found that involving the employees in the digital transformation process and initiatives, as well as ensuring appropriate culture, training, and leadership is important to engage the employees in the digital transformation. Employee engagement, in turn, is found to contribute to incumbent firms' digital transformation success.

Third, and against this backdrop, in the articles included in this thesis I explore directly or indirectly different ways in which incumbent firms should involve their employees in digital transformation. Put together, the insights gained from the articles confirm the importance of taking the employee into consideration when embarking on a digital transformation.

For instance, in the first article, we illustrate how digital transformation prompts changes to employee competence requirements. Incumbent firms should acknowledge potential competence gaps and involve the employees in the digital transformation through carefully listening to them to understand their needs and interests and to uncover any hidden competencies. Moreover, incumbent firms should involve the employees in the digital transformation by investing in them and continuously helping them in developing their competencies in line with what the organization requires, needs, or expects during and post-transformation.

In the second article, we illustrate the importance of involving employees in digitalization efforts as part of the larger digital transformation. We argue that continuous development—which relies on heavy employee involvement and learning—is a fruitful approach for incumbent firms in developing digital solutions or embracing digitalization efforts in general. Through actively involving the employees at the operational level through dynamic interactions with middle and top management, incumbent firms can reduce initial resistance towards new digital technology or accompanying changes and gain valuable learning to ensure that digitalization efforts meet the needs and requirements of the employees. Thereby, incumbent firms can achieve engaged employees in their digital transformation without having to invest heavily in change management.

In the third article, we illustrate different mechanisms that can enable incumbent firms to influence how employees understand and interpret complex digital artifacts as introduced to them in the digital transformation. For employees to apply a digital artifact in their work context, prevailing affordance-based IS research has shown that the employees need to understand which action possibilities the artifact offers them (i.e., affordance actualization requires affordance perception). We argue that it is not enough for the employees to understand the features of the digital artifact; they also need to understand the tasks they could perform with it, the purposes of performing these tasks, and the identity they could assume in doing so. To accomplish this, heavy employee involvement throughout the development process is crucial, as well as, for instance visualizing to the employees the potential application areas of the digital artifact during its development, allowing the employees to test the solution along the way, and challenging the employees to think through their tasks and processes in the present and where they want to be. These mechanisms, in turn, can help incumbent firms ensure that employees understand (and eventually apply) the digital artifact as intended by the organization and in line with their overarching digital transformation objectives.

In the fourth article, we illustrate the value of incumbent firms engaging in co-creation together with experienced external actors in developing complex digital artifacts. Moreover, we illustrate the importance of involving the employees as potential users of the digital artifact in this co-creation, which is in line with prevailing IS research. In our case, the development of the digital artifact would not have succeeded without the input and contributions from the employees, which I again would argue enables the incumbent firm to ensure that the future application of the artifact is congruent with their overarching digital transformation objectives.

Collectively, my research also offers valuable insights and implications for practice. Through my research I illustrate to practitioners what digital transformation could entail for incumbent firms and offer valuable insights into how digital transformation prompts changes to employee competence requirements (Article 1), the value of involving employees in digitalization efforts, interactions, and co-creation as part of the larger digital transformation (Articles 2 and 4), and how and why employees understand complex digital artifacts in the context of digital transformation (Article 3). Moreover, through each article I offer promising ways in which incumbent firms could embrace digital transformation and face the common challenges incumbent firms may encounter during such transformations, and particularly highlight the importance of and approaches to involving employees in the digital transformation. Returning to George Westerman's (2016) quote from earlier; just as we should not forget it is people who make companies work, we must also not forget that it is people who make digital transformation work.

6.2 Implications for research and practice from each individual article

Besides the overall contribution of my research, the insights derived from each individual article have specific implications for research and practice. In the first article we specifically contribute to the IS literature by exploring employee competencies from a digital transformation perspective; a topic that, despite the agreement that digital transformation affects competence requirements, has received limited attention in IS research to date (Butschan et al., 2019; Shahlaei et al., 2017). First, we introduced the concept of digital transformation competence and developed a conceptual model to clarify the relationships and differences between digital transformation capabilities and digital transformation competencies. Our suggested definition and model should help IS researchers in exploring competencies in relation to digital transformation in other contexts. Further, we identified key employee competencies essential for incumbent firms in their digital transformations (i.e., digital transformation competencies) and developed a generic model for obtaining such competencies. This article therefore provides IS researchers with valuable insights towards achieving a better understanding of digital transformation and ways for incumbent firms to accomplish such transformations, which we hope will be helpful also for practitioners embarking on digital transformations.

In the second article we contribute to IS research by theorizing and exploring the idea of continuous development in the broader organizational context of digital infrastructure evolution. We suggest a theoretical definition of continuous development, which should help IS researchers explore this phenomenon in other organizational contexts. We also propose a model to understand and illustrate how actors across different organizational levels interact to enable the continued growth and increasing benefits of digital solutions. Our findings and model offer IS researchers a nuanced perspective on both digital infrastructure evolution and sense-making and sense-giving mechanisms in the context of digitalization and digital transformation. In the case of GridCo, the continuous development of the OPRA infrastructure was considered by the case organization as a "revolutionary" digitalization effort and important contributor to their overall digital transformation. Hence, with this article, we also contribute to both research and practice in bringing to light digital infrastructures as important ingredients in incumbent firms' digital transformations and the value of constructive interactions between operational employees and other organizational actors. Moreover, this article offers a new way for practitioners to think about digitalization and digital transformation, which is increasingly relevant as the ability for firms to engage in continuous development in broader organizational contexts is increasing with maturing digital technology (Berente, 2020; Dingsøyr & Lassenius, 2016; Lindgren & Münch, 2016).

In the third article, following the digital twin project at GridCo over time, we were able to develop an understanding of how and why employees perceived digital twin affordances through a Heideggerian lens. Through our theoretical model we contribute to the existing discourse on affordances in IS research by offering a nuanced perspective on affordance perception, hence increasing our understanding of the relational aspect of affordance perception. The insights derived from the study are also valuable for managers and developers in that we offer insights into mechanisms that help influence and increase familiarity with the referential totality of a digital artifact, which in turn also influences affordance perception and eventually application of the digital artifact.

Research on digital twins is still in its infancy (Kritzinger et al., 2018), and with this article we also contribute to IS research and practice by exploring how digital twins are understood (and potentially applied) by employees. This is important in the context of digital transformation, because digital twins are predicted as key ingredients in and drivers of firms' digital transformations (Saracco, 2019). This is arguably particularly the case for incumbent, asset-centric firms, such as GridCo, where data typically exist in separate organizational silos, which can be combined in a digital twin (Dietz & Pernul, 2020). Prevailing IS research on digital twins has mainly focused on conceptualizations and providing frameworks for digital twin implementation (e.g., Cimino et al., 2019), as well as presenting insight on digital twin use cases (Enders & Hoßbach, 2019). The literature states that there are large benefits of digital twin applications in several industries; however, there is a need for more case studies applying the concept in practice (Kritzinger et al., 2018), to which we hope to contribute with this study, in particular by exploring how such complex digital artifacts are understood by potential users (and in Article 4, how digital twins could be developed through co-creation).

With the fourth article, we aimed mainly at contributing to practitioners; however, because research on digital twins is, as mentioned above, still nascent (Kritzinger et al., 2018), this work does provide valuable insight to IS researchers on what digital twins are and how such complex digital artifacts can be developed through co-creation, as well as how digital twins may serve as important ingredients in incumbent firms' digital transformation (Saracco, 2019). Nevertheless, with this article we mainly contribute to practitioners in illustrating both the possible applications of digital twins, but perhaps more importantly, how co-creation can serve as a prerequisite for successful digital twin development.

7. Concluding remarks

With this research I aim at contributing to IS research and practice in further delineating important and unresolved aspects of digital transformation in incumbent firms and shedding light on the importance of involving the employees during such transformations. Through the opportunity to follow an incumbent firm over time in their digital transformation, I have gained rich insight into important and challenging aspects of digital transformation, which I hope, through building on relevant theoretical perspectives, conducting thorough analysis, and collaborating with prominent IS researchers through co-authorship, will prove valuable for the IS field and practitioners engaged in or planning to engage in digital transformations.

7.1 Limitations and avenues for future research

Digital transformation is a complex and compound process and phenomenon, and I may have interpreted aspects of GridCo's digital transformation in ways that may differ from that of other researchers. However, I have built on existing literature on digital transformation and well-established theoretical foundations, collected and analyzed data thoroughly and consistently, and reported in detail the data and analytical approaches to illustrate clear chains of evidence (Yin, 2014). Nevertheless, since digital transformation is such a complex and compound process, other researchers might have approached similar research in different manners; hence, further research on digital transformations in incumbent firms should be conducted to confirm and strengthen our findings.

Drawing on insight from one case organization only, although generating rich and in-depth insight, high credibility, and excluding confounding variables introduced by the heterogeneity of organizational contexts, comes with some limitations. Some may argue that our findings may not be directly applicable to other contexts; however, I would still argue that the way in which I conducted data collection, analysis, and presented our findings with transparency, rigor, and a focus on details allows for our theoretical propositions (i.e., models, definitions, conceptualizations) to be generalized and transferred to other situations and contexts (Yin, 2014). Nonetheless, the different aspects of digital transformation that I have theorized and explored in my research should be further investigated, and our theoretical propositions explored in other contexts, with other digital artifacts, or other digitalization efforts, to test their tenability.

The grid sector in Norway has its peculiarities and the Scandinavian workplace model is considered somewhat unique (Bygstad et al., 2017; Garmann-Johnsen et al., 2018), which may have had some influence on how the digital transformation in the case organization unfolded, and the ways in which employees were taken into consideration through, for instance, heavy employee involvement and interactions in development and co-creation. Research has shown that the Scandinavian workplace model and culture is rather unique in its relatively high degree of democracy, based on cooperation, consensus, participation, low power distance, and good working relationships (Bygstad et al., 2017). Nevertheless, although the case context may be considered rather unique, I believe that the Scandinavian model offers something valuable to incumbent firms in other contexts from them to learn from. Moreover, the way in which GridCo have embarked on their digital transformation journey offers valuable learning for IS researchers and should serve as inspiration for other companies in other industries and countries.

Regarding the employee dimension, I have explored ways in which and why employees might be affected by the digital transformation (e.g., through changes in competence requirements), be involved in digitalization efforts through interactions and co-creation, and understand complex digital artifacts in specific contexts (i.e., digital twin). There are, however, still aspects of the employee dimension that I did not cover in my research, and that remain uncertain and should be investigated further in future research. This includes for instance how the employees themselves experienced the digital transformation. Although I mainly interviewed operational employees in my research, and some of them shared with me how they experienced the digital transformation, this was not something I pursued in delineating further in my research.

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Thesis articles

Submission process and latest status

ARTICLE 1
Osmundsen, K. & Iden, J. **Digital transformation and the need for new competencies**

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ARTICLE 4
Meske, C., Osmundsen, K., & Junglas, I. **Co-creating a digital twin for the energy sector**

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Article 1

Title: Digital transformation and the need for new competencies

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Abstract: Many incumbent firms are undergoing *digital transformations* to remain relevant and competitive in the digital era. The integration of new digital technologies following digital transformation requires new competencies among firms' employees; however, there is limited insight into which specific competencies are essential for succeeding with digital transformation and how these competencies should be obtained. To reduce this gap, we conducted a longitudinal case study of a large Norwegian grid company, exploring how competence requirements shifted during digital transformation. Drawing on relevant IS literature on capabilities and competencies, we conceptualized the concept *digital transformation competence*, identified competencies that are essential for digital transformation, and developed a generic model of approaches for incumbent firms to obtain digital transformation competencies. Our research contributes to both research and practice by unpacking the concept of digital transformation competence and, hence, increasing our common understanding of what digital transformation entails and how incumbent firms should embrace digital transformation.

Keywords: digital transformation, digital transformation competence, competence, competencies, incumbent firms

1. Introduction

The term *digital transformation* has gained increasing attention in both research and practice in recent years (Hanelt et al., 2020; Vial, 2019; Wessel et al., 2020), referring to major organizational changes driven by technological change in environmental and organizational contexts (Wessel et al., 2020). Digital transformation is particularly challenging for incumbent firms (Chanias et al., 2019; Sebastian et al., 2017; Svahn et al., 2017; Warner & Wäger, 2019); however, necessary for these companies to remain relevant and competitive in the digital era (Nambisan et al., 2019; Sebastian et al., 2017). Because digital transformation inherently implies integration of new digital technologies (Liu et al., 2011; Reis et al., 2018; Wessel et al., 2020), new competencies are required to adopt, master, and manage these new digital technologies (Butschan et al., 2019; Gupta et al., 2018; Kensbock & Stöckmann, 2020; Kozanoglu & Abendi, 2020; Vial, 2019). Accordingly, ensuring appropriate competence is crucial for the successful digital transformation of incumbent firms (Kozanoglu & Abendi, 2020). This is supported by Westerman and colleagues (2012), who found that over two-thirds of the executives they interviewed mentioned competence gaps across the entire organization as a hindrance to digital transformation; however, little is known about which IS-related competencies are essential for digital transformation (Butschan et al., 2019), or how these competencies can be obtained, which this study aims to determine.

IS-related competencies have been a topic of interest in the IS field since the 1990's (Wade & Hulland, 2004). Accordingly, the IS literature has enrichened our understanding of the importance of IS related competencies both on an organizational level and particularly among managers and IS professionals, for instance for gaining competitive advantage, superior performance, IS success, innovativeness, and organizational agility. There is, however, limited empirical evidence of IS-related competencies important for organizations in succeeding with digital transformation (Butschan et al., 2019). In the context of traditional IS-induced organizational transformation (such as the implementation of enterprise resource planning (ERP) systems), research has mainly focused on the competencies required of managers to oversee the implementation (e.g., Kræmmergaard & Rose, 2002) and the organizational and individual competencies for successful technology adoption and use (e.g., Caldeira & Ward, 2002; 2003). Digital transformation, however, represents a different and more extensive transformation than the traditional IS-induced organizational transformations we have witnessed for decades (Chanias et al., 2019; Hanelt et al., 2020; Li et al., 2018; Vial, 2019; Wessel et al., 2020), involving changes to the organizations' business model and organizational identity (Wessel et al., 2020). Moreover, digital transformation involves integration of several digital technologies, often in combination (Bharadwaj et al., 2013)—digital technologies exhibiting properties such as generativity, malleability, and combinability (Kallinikos et al., 2013). Exploring and exploiting the potential of novel digital technologies during digital transformation affects employees across the entire organization (Kensbock & Stöckmann, 2020), and not merely managers or the IT function. Accordingly, because of the characteristics of digital transformation (Vial, 2019; Wessel et al., 2020) and the extent to which incumbent firms are required to undergo digital transformations to stay competitive (Nambisan et al., 2019; Sebastian et al., 2017), there is a need for more insight on how digital transformation affects the competence needs of incumbent firms (Kensbock & Stöckmann, 2020).

When undergoing digital transformations, firms should take advantage of existing strengths and competencies and, simultaneously, develop relevant competencies and exploit new digital technology (Gupta et al., 2018). However, insight into how firms can accomplish this strategy (Eden et al., 2019), and which competencies are particularly important for firms embracing digital transformation, is limited (Butschan et al., 2019; Shahlaei et al., 2017). We seek to reduce this gap, theoretically, by conceptualizing *digital transformation competence* as a firm's bundle of collective employee competencies that are essential for succeeding in digital transformation and remaining competitive in the digital era. Further, we construct a model to categorize the concept *digital transformation competence*, nested in the knowledge, skills, and abilities of employees, in relation to the firm-level concept *digital transformation capability* (Wiesböck & Hess, 2018). Empirically, we investigated which digital transformation competencies were essential for an incumbent firm's digital transformation and how these competencies were obtained. Accordingly, our research questions are:

- Which competencies are essential for digital transformation?
- How can incumbent firms obtain digital transformation competencies?

Our empirical approach involved a longitudinal case study of a Norwegian grid company undergoing digital transformation. By following the case organization over time and gathering extensive data through interviews, observations, and document studies, we were able to uncover a shift in competence requirements prompted by the digital transformation. We identified 14 digital transformation competencies; competencies that were new to the company and which were perceived as essential in their digital transformation, encompassing new knowledge, skill, and ability requirements of employees across the entire organization (both IS professionals and non-IS professionals). Our research contributes to both research and practice by unpacking the concept of digital transformation competence and, hence, increasing our common understanding of what digital transformation entails and how incumbent firms should embrace digital transformation.

The paper continues as follows: First, we present the contextual background of our study and relevant literature related to competencies within the IS field, including a clarification of central concepts and conceptualization of the concept digital transformation competence. Our research approach is then described, followed by a presentation of our results. In the discussion, we return to our research questions, first seeking to highlight and generalize which competencies are essential for incumbent firms' digital transformation and, second, presenting a generic model of approaches for obtaining digital transformation competencies and emphasizing important measures managers should consider for obtaining, maintaining, and developing the relevant competencies. Finally, we highlight avenues for future research, and point out the limitations of our study, before concluding the paper.

2. Contextual background and relevant literature

2.1 Contextual background: digital transformation in incumbent firms

The contextual background for this study is digital transformation in incumbent firms. Digital transformation can be understood as a process by which organizations set out to improve their business by combining and utilizing digital technology, data, and information (Vial, 2019). Motivated and incentivized by technological changes in organizational and environmental contexts (Wessel et al., 2020), digital transformation implies organizations partly or completely altering the way they do business (Sebastian et al., 2017). A digital transformation is a prolonged process consisting of several combined digitalization projects and organizational change initiatives (Heilig et al., 2017; Osmundsen et al., 2018), often based on a digital business strategy (Bharadwaj et al., 2013). To initiate, coordinate, and oversee digital initiatives and overall digital transformation, firms often establish digital innovation units or nominate chief digital officers (CDOs; Haffke et al., 2016). Furthermore, a digital transformation often requires a cultural change in the organization, toward a digital culture characterized by willingness to learn and openness to change (Hartl & Hess, 2017). Since digital transformation is driven by technological change, new competencies are required to enable employees to adopt and master new digital technologies, and to integrate the technologies into processes, services, and products (Butschan et al., 2019; Gupta et al., 2018; Kensbock & Stöckmann, 2020; Kozanoglu & Abendi, 2020).

Organizations have experienced IS-induced organizational changes for decades (Li et al., 2018; Wessel et al., 2020). Whereas traditional IS-induced organizational change mainly concerned improving business processes and reducing costs related to implementation of internal information systems such as ERP (Li et al., 2018), digital transformation is typically externally driven, and goes far beyond internal business processes to also involve changes in organizations' business models and identities (Wessel et al., 2020). Accordingly, digital transformation affects the entire organization (Kensbock & Stöckmann, 2020), and involves organizational actors within all business areas (not merely the IT function) and across all organizational levels (not merely managers).

Digital transformation can be particularly challenging for incumbent, non-born-digital firms (Chanias et al., 2019; Sebastian et al., 2017; Svahn et al., 2017; Warner & Wäger, 2019), because they typically rely on established assumptions that may constrain them from engaging in digital initiatives (Engesmo & Panteli, 2020; Westerman & Bonnet, 2015). Incumbent firms can be understood as established firms in traditional industries "that were financially successful in the pre-digital economy, but to which the digital economy poses an existential threat" (Chanias et al., 2019, p. 17). While born-digital firms, such as Google and Airbnb, can exploit networking for rapid growth (Parker et al., 2016), incumbent firms evolve more slowly and must combine digital and physical elements in their digital transformation.

Consequently, incumbent firms face the challenge of continuously balancing new opportunities with established practices (Svahn et al., 2017). Since digital transformation inherently implies the integration of new digital technologies (Wessel et al., 2020), incumbent firms are forced to alter their entire organizations and business models to adopt the digital technologies (Bharadwaj et al., 2013; Chanias et al., 2019; Sebastian et al., 2017; Tumbas et al., 2017). Accordingly, digital transformation involves a holistic organizational transformation enabled by digital technology (Chanias et al., 2019), which often involves a transformation of the workforce (Eden et al., 2019).

2.2 Capabilities and competencies within the IS field

Capability is a firm-level construct associated with putting resources (and other inputs) into action (Dosi et al., 2000). Capabilities can be functional (e.g., IS capability), specialized (e.g., business intelligence capability), or cross-functional (e.g., new product development (NPD) capability). Competencies, on the other hand, are combinations of knowledge, skills and abilities (KSAs) as manifested in the firm's employees (Nordhaug & Grønhaug, 1994; Peppard & Ward, 2004). Knowledge implies having an understanding of the technical, practical, and social aspects of a task in a certain context (Caldeira & Ward, 2003; Cheney et al., 1990), while skills refer to the capacity to perform the task, and involves evaluating possible actions, selecting the most appropriate solution, and performing the task itself (Caldeira & Ward, 2003; Cheney et al., 1990). Finally, abilities relate to personal traits, such as behaviors, attitudes, and aptitudes that "make knowledge useful and enable skills to be acquired in the first place" (Peppard & Ward, p. 181). In the literature, there is a distinction between competence and competency. Where a competency can be viewed as a specific area of knowledge, skill, or ability; competence is the state of having sufficient knowledge, skill, or ability (Tsohou & Holtkamp, 2018). In this study, we use the terms interchangeably, depending on what we are addressing.

The literature has typically distinguished between *general competence* and *firm-specific* (or specialized/unique) *competence* (Barney & Wright, 1998; Flamholtz & Lacey, 1981; Lepak & Snell, 1999; Nordhaug & Grønhaug, 1994). General competences are typically generated through education (Lepak & Snell, 1999; Nordhaug & Grønhaug, 1994); they are valuable to the firm, but are also transferable to, and applicable in, other firms. Firm-specific competences, on the other hand, are typically generated through procedural experience and training, are linked to the idiosyncrasy of the firm (Lepak & Snell, 1999; Nordhaug & Grønhaug, 1994), and are thus potentially less valuable for other firms and harder for them to imitate. Examples of firm-specific competence include the skills and abilities to use firm-specific technology or knowledge of a firm's policies and processes (Barney & Wright, 1998).

The IS literature concludes that technology itself has limited competitive value and that technology alone is unlikely to create sustained competitive advantage (Peppard & Ward, 2004; Wade & Hulland, 2004), because investments in technology are often easily imitated by competitors (Bharadwaj, 2000).

Building on that notion, IS researchers have investigated which *IS capabilities* and *IS competencies* (see Table 1 for definitions) are necessary to make IS investments effective (Wade & Hulland, 2004). This research has enrichened our understanding of the IS competencies important for achieving for instance IS success (Cragg et al., 2011), organizational agility (Chakravarty et al., 2013; Ravichandran, 2018), innovativeness (Tarafdar & Gordon, 2007), firm performance (Chakravarty et al., 2013; Peppard & Ward, 2004), competitive advantage (Gupta et al., 2018), and during turbulent environments (Chakravarty et al., 2013; Pavlou & El Sawy, 2006; Ravichandran, 2018). In light of IS-business alignment and technology implementation and adoption, the IS literature has particularly focused on the IS-related competencies of managers (e.g., Basselier et al., 2003; Harison & Boonstra, 2009; Kræmmergaard & Rose, 2002; Weigel et al., 2020; Ylijoki and Porras, 2019) and the competencies of IS professionals (e.g., Akman & Turham, 2018; Klendauer et al., 2012; Lee et al., 1995; Persaud, 2020; Wu, 2009).

With the growing attention on digital transformation in IS literature (Vial, 2019; Wessel et al., 2020), the concept *digital transformation capabilities* has emerged to denote the capabilities necessary for digital transformation. Following Wiesböck and Hess (2018), digital transformation capability is firm-level construct and can be understood as an "organization's ability to implement digital business concepts that complement digital solutions (i.e., handle the process of digital transformation)" (p. 10). Building on this notion, and the IS competency literature, we propose the concept of digital transformation competency which we define as "a firm's bundle of collective employee competencies (knowledge, skills, abilities) that are essential for succeeding in digital transformation and remaining competitive in the digital era". In Table 1, we have summarized central concepts and related definitions, leading up to this concept, which has received limited attention in IS research to date (Butschan et al., 2019). In fact, a recent search in top IS journals addressing digital or organizational transformation and competencies provided only eight results[1]. This is in line with other researchers' observations, in that digital transformation literature taking into account the employee perspective is scant (e.g., Kensbock & Stöckmann, 2020; Kozanoglu & Abedin, 2020). Besides some valuable contributions on for instance exploring employee skills (e.g., Sousa & Rocha, 2019; van Laar et al., 2017; 2019) and the role and attributes of managers (e.g., von Ohain, 2019; Harison & Boonstra, 2009; Singh & Hess, 2017; Singh

[1] Search conducted in SCOPUS on November 2nd, 2020 in the 21 journals rated as 4*, 4, or 3 within the field "Information Management" in the Academic Journal Guide 2018 for articles including terms digital transformation / organizational transformation / organizational change and competence(s) / competency(ies) in their title, abstract, or keywords.

et al., 2020) important for digital transformation, research on IS-related competencies in digital transformation contexts is still nascent (Butschan et al., 2019).

Table 1. Central concepts and definitions (capabilities and competencies)

Capability	**Definition**	**Competency**	**Definition**
Capability	A firm's "ability to assemble, integrate, and deploy valued resources, usually, in combination or copresence" (Bharadwaj, 2000, p. 171)	Competency	"Work-related knowledge, skills, and abilities" (Nordhaug & Grønhaug, 1994, p.91)
IS capability	A firm's "ability to mobilize and deploy IT-based resources in combination or copresent with other resources and capabilities" (Bharadwaj, 2000, p. 171)	IS competency	The set of IS-related knowledge and experience that organizational actors possess (Basselier et al, 2003)
Digital transformation capability	A firm's "ability to implement digital business concepts that complement digital solutions (i.e., handle the process of digital transformation)" (Wiesböck & Hess, 2018, p. 10).	Digital transformation competency	A firm's bundle of collective employee competencies (knowledge, skills, abilities) that are essential for succeeding in digital transformation and remaining competitive in the digital era (elaborated in the next section)

2.3 Competencies essential for digital transformation

There are at least four reasons why it is necessary to revisit the concept of competencies in the context of digital transformation. First, digital transformation inherently involves integration of several digital technologies (Reis et al., 2018; Wessel et al, 2020), often in combination (Bharadwaj et al., 2013), and including a robust infrastructure with advanced APIs (Vial, 2019). Which digital technologies are applied and combined in the digital transformation varies between firms, and is often linked to the digital trends in the sector in which the firm operates (Kettunen & Laanti, 2017). Some examples of digital technologies in firms' digital transformations are included in Table 2.

Table 2. Examples of digital technologies involved in firms' digital transformations

Digital technologies in digital transformation	**Example source(s)**
Artificial intelligence (AI)	Alexander & Lyytinen, 2017; Kolbjørnsrud et al., 2016; Sousa & Rocha, 2019
Augmented reality (AR)	Sousa & Rocha, 2019
(Big) data analytics	Alexander & Lyytinen, 2017; Dremel et al., 2017; Kettunen & Laanti, 2017; Khin & Ho, 2018; Liu et al., 2020; Persaud, 2020; Westerman et al., 2012; Ylijoki and Porras, 2019
Cloud technology	Andriole, 2018; Benlian et al., 2018; Du et al., 2016; Heilig et al., 2017; Kettunen & Laanti, 2017
Digital platforms	Hinings et al., 2018; Kozanuglo & Abendi, 2020
Digital twin	Liu et al., 2018
Internet of Things (IoT) & sensor technology	Butschan et al., 2019; Dery et al., 2017; Heilig et al., 2017; Kettunen & Laanti, 2017; Kettunen & Mäkitalo, 2019; Sousa & Rocha, 2019
Mobile (applications (apps) & technology)	Berman, 2012; Heilig et al., 2017; Khin & Ho, 2018; Sousa & Rocha, 2019; Westerman et al., 2012
Robotic process automation (RPA)	Andriole, 2018; Osmundsen et al., 2019; Sousa & Rocha, 2019
Social media	Khin & Ho, 2018; Oestreicher-Singer & Zalmanson, 2013; Westerman et al., 2012

Second, unlike traditional enterprise systems, today’s digital technologies are disruptive (Karimi & Walter, 2015; Nambisan et al., 2019), and exhibit new properties; they are generative, malleable, and combinatorial (Kallinikos et al., 2013). Third, in digital transformation, these technologies are applied to uncover new paths for value creation, unlike traditional enterprise systems that were mainly applied for streamlining existing processes and improving existing products and services. Fourth, exploring and exploiting the potential of novel digital technologies involves and affects employees across the entire organization (and not merely IS-professionals). Accordingly, as new technologies are introduced in a firm, new knowledge, skills, and abilities are required for employees across the organization to adopt the new technology and adapt to the changes that follow the transformation (Butschan et al., 2019; Gupta et al., 2018; Vial, 2019). Hence, we argue that digital transformation requires firms to obtain *digital transformation competences*.

For the purpose of this paper, to clarify the terminology, we organized the concepts *digital transformation capability* and *digital transformation competence* into a conceptual model, inspired by Peppard and Ward’s (2004) IS capability model (see Figure 1).

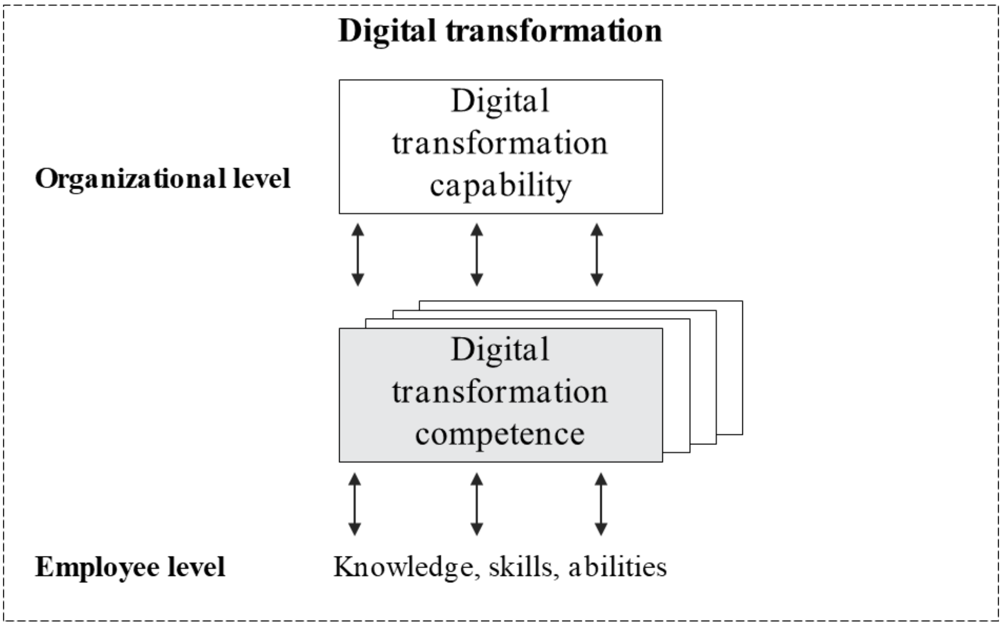

Figure 1. Digital transformation capability and competence (inspired by Peppard and Ward [2004])

As illustrated in Figure 1, digital transformation capability is the firm's ability to manage digital transformation (Wiesböck & Hess, 2018), and is a construct at the organizational level. In order to achieve digital transformation capability firms need digital transformation competence, which is embedded in employee knowledge, skills, and abilities. The digital transformation competencies reflect the necessary competence base for digital transformation, and includes the firm's ability to combine these attributes in responding to and managing the digital transformation.

To summarize, digital transformation requires new competencies, and there is a need for insight into particular IS-related competencies that are essential in the context of digital transformation in incumbent firms. This is in line with the recommendations of Kozanoglu & Abedin (2020), who in their conceptual paper argue that employees' knowledge, skills, and abilities are essential in a firm's digital transformation success, however; that this perspective is largely neglected in prevailing digital transformation literature. The studies of for instance Butschan and colleagues (2019), and Kensbock and Stöckmann (2020), represent a good starting point for this endeavor, however; there is still a need for more empirical evidence from firms undergoing digital transformations. In this paper, we explore and further develop the concept of digital transformation competence through a qualitative case study, as described in section 3.

3. Research approach

We conducted a longitudinal case study at an incumbent firm in Norway. A case study of this type involves studying a case within a real life, contemporary context over time, through detailed, in-depth data collection from multiple sources of information (Creswell, 2012). The research was longitudinal, since we followed the case organization with one author spending 1–3 days per week in the case organization for almost two years (September 2018–July 2020). Wide access to the case organization enabled us to develop a deep understanding of the organization and its digital transformation, and in-depth insight into how competence requirements evolved over time. Our research approach was inductive, in that we during preliminary data collection identified a competence shift in the organization, which encouraged us dig deeper into competencies from a digital transformation perspective.

3.1 Case setting

The case organization, referred to as GridCo, is one of the oldest and largest grid companies in Norway, founded in the early 1900s and employing approximately 500 people. GridCo is responsible for building, operating, and maintaining the regional and local distribution network within a specific geographic area in Norway and, thus, providing electricity to their customers. Customers, here, refer to consumers of electricity (i.e., both private households and industry customers). The company has a long tradition of fulfilling its obligation to provide electricity to more than 240,000 grid customers through more than 27,000 km of aerial power lines and underground power cables.

Because it is not economically viable to build adjacent grid networks, each grid company in Norway has held a monopolistic position in a specific geographical area of operation. Furthermore, because consumers need electricity, and because electricity can only be provided by grid companies, grid companies have had safe and stable positions for decades. Recently, however, environmental and grid sector changes have begun to challenge the traditional roles and monopolistic positions of the grid companies, including market trends, industry convergence, and shifting customer expectations and demands. The entire system for producing, distributing, storing, and consuming energy is changing, due to evolving trends such as electrification and local energy solutions (microgrids). Moreover, an increasing number of digital elements and smart components, such as automated meter reading (AMR), are being incorporated in all layers of the energy network (Kettunen & Mäkitalo, 2019) in Norway. With AMR technology, grid companies can collect accurate and almost real-time data for energy consumption. AMR data, in combination with other available data, can provide grid companies with a richer and more accurate foundation for improving services and satisfying customers. Simultaneously, new competitors, ranging from large enterprises and non-industry entrants to small startup companies, are entering the grid sector. In the Norwegian context in particular, regulators are introducing regulations and guidelines that may change the dynamics of the industry, leading the players toward cooperation, changed roles, new business models, and new ways of approaching customers.

With all the changes occurring in the sector and environment, GridCo realized that they needed digital transformation in order to leverage digital developments, prepare the organization for the future, and remain relevant and competitive. Among other changes, GridCo's digital transformation involved a competence shift for the GridCo's workforce. As one manager explained, about the changes in competence needed by the company:

There will be many more "thingies" to assemble in the future. Raising a pole is really rather rough, mechanical work, but if that pole is equipped with a sensor or similar, the electrician will have to know something about sensor technology and how the sensors communicate—to be sure that he or she assembles it correctly (Interviewee 13).

In this study, we deeply investigated these competence changes, explored which competencies are essential for the digital transformation of an incumbent firm such as GridCo, and how such competencies could be obtained.

3.2 Data collection

We relied on three sources of data for our research: interviews, observations, and archival data. The data sources are summarized in Table 3 and elaborated below.

Table 3. Overview of data sources and use

Data source	**Data collection (no. of respondents)**	**Purpose and use in analysis**
Semi-structured interviews with 45 respondents (some of whom were interviewed more than once)	Conducting preliminary interviews (12)	Understand the history of the case company, respondents' perceptions of the firm' strengths and weaknesses, and the digital transformation challenges. Included interviews with representatives from various organizational levels. During this phase, a shift in competence requirements in relation to digital transformation was identified.
	Interviewing top management and middle management respondents (18)	Understand how managers perceived and dealt with changes in competence requirements; understand the perceived challenges of top and middle management in managing the digital transformation, which initiatives they initiated, and the measures they took to meet these challenges
	Interviewing operational level respondents (27)	Understand how digital transformation initiatives potentially changed the ways of working and competence requirements of operational employees
Observations	Spending 1–3 days per week in the case organization for 2 years, working alongside employees, overseeing discussions and formal/informal meetings, and engaging in conversations	• Provide insight into existing competencies, and new competence needs • Provide insights into the case organization's culture and ways of working, and follow relevant discussions and topics of interest over time • Provide insight into relevant aspects of the case company and its digital transformation that could be further probed for data collection • Support and triangulate the interview data
	Presenting ideas to case company representatives at different occasions	Validate interpretations and clarify uncertainties or misunderstandings

Archival data	Accessing documents through a document archive system, collaboration platform, and other information systems	• Provide information about the case company and its digital transformation, for example:
		  o strategic aims
		  o digitalization initiatives and projects
		  o digital technology implementations
		• Provide information about the competence base over time, for example:
		  o competence plans
		  o employee overviews
		  o recruitment history and plans
		• Support and triangulate the interview data

We conducted semi-structured interviews with 45 respondents holding different positions in different departments of the company. Some respondents were interviewed more than once. Interviews were conducted between November 2018 and September 2019. During the preliminary interviews with respondents across different organizational levels, we identified a shift in competence requirements following GridCo's digital transformation. This encouraged us to include a focus on competencies in the subsequent interviews with managers and operational employees. In total, the interview respondents included 4 top management representatives, 14 middle management representatives, and 27 operational-level employees. Each interview lasted between 30 min and 2 h. The interviews were tape recorded, with the respondents' consent, and transcribed verbatim. Overall, the interviews generated more than 500 written pages of transcripts. Table 4 presents an overview of the interview respondents, their organizational levels and departments (administration, development, execution, or system operations), together with the duration of the interviews.

Table 4. Overview of interview respondents

Organizational Level/Department	**Number of Respondents**	**Duration of interviews**
Top Management	4	216 min/3.6 h
Administration	*1*	*55 min/0.9 h*
Development	*1*	*47 min/0.8 h*
Execution	*2*	*114 min/1.9 h*
Middle Management	14	914 min/15.2 h
Development	*5*	*274 min/4.6 h*
Execution	*7*	*451 min/7.5 h*
Systems Operations	*2*	*189 min/3.2 h*
Operational Level	27	1,289 min/21.5 h
Development	*6*	*312 min/5.2 h*
Execution	*21*	*977 min/16.3 h*
In Total	**45**	**2,419 min/40.3 h**

Observations were another important source of data, enabling us to view the organization from an insider perspective (Jorgensen, 1989). Since one researcher spent 1–3 days in the organization for almost two years, we were able to conduct detailed observations by overseeing discussions, working alongside employees, participating in lunchtime talks, and attending numerous meetings, including department, project, management, and staff meetings. This presence in the organization enabled us to follow the firm's digital transformation closely, including the discussions on competence gaps and changes in competence requirements. Observations were documented in over 100 pages of field notes, constituting a valuable data source and foundation for data analysis.

Our study also included extensive archival data, accessed through the organization's document archive system, collaboration platform, and other company information systems. This data included strategy documents, competence plans, presentations, budgets, and a significant number of postings and news items on the internal communication platform. In particular, insight into GridCo's competence plans and recruitment history enabled us to capture how the company addressed competence over time.

3.3 Data analysis

We applied thematic analysis to analyze our data: a useful and flexible method for identifying, analyzing, and reporting patterns (themes) in qualitative data (Braun & Clarke, 2006). *Themes* refer to abstract constructs identified by researchers before, during, and after analysis, which capture important aspects of the data in relation to the overarching research questions. We chose a theoretical approach to our thematic analysis (i.e., our analysis was driven by our theoretical interests and overarching research questions). We followed six steps in analyzing our data, inspired by Braun and Clarke (2006) (see Table 5).

Table 5. Data analysis steps (inspired by Braun & Clarke [2006])

Step	Activities	Outcome
1. Familiarizing ourselves with the data and capturing the "story"	Transcribing data, reading and re-reading transcripts, noting initial ideas, identifying major events, writing case notes, understanding path toward digital transformation competence, and constructing a timeline	• Interview transcripts • Ideas for subsequent steps • Case setting • Path toward digital transformation competence • Timeline with events (Figure 2)
2. Generating themes	Choosing themes according to the theoretical perspective and conceptual model	• Themes: firm-specific and general competencies
3. Coding the data	Coding data, and reviewing and refining codes and data extracts	• Coding data extracts according to four themes: firm-specific (develop), firm-specific (collaborate), general (acquire), general (rent)
4. Empirical analysis	Collating codes into themes, gathering data relevant to each theme, generating thematic map, analyzing coded extracts, identifying digital transformation competencies	• Thematic map • Digital transformation competencies (Table 6)
5. Theoretical analysis	Understanding digital transformation competencies in relation to literature, conceptualizing how digital transformation competencies could be obtained	• Approaches for obtaining transformation competencies (Figure 3)
6. Producing report	Selection of extracts, final analysis, logical illustrations, relating back to research questions and literature	

In the first step, interviews were transcribed verbatim. The interview transcripts, observational field notes, and relevant documents were read and re-read, which enabled us to familiarize ourselves with the data, resulting in ideas for the subsequent steps of the analysis and providing a thorough understanding of the case organization. We tried to capture the "story" (Miles et al., 1994) of competence development in GridCo in relation to digital transformation. We constructed a timeline of major events (Figure 2) and linked this timeline to competence implications for GridCo. The timeline was verified by relevant sources at GridCo to ensure that our understanding was accurate.

In the second step, we generated themes for further data analysis, driven by our theoretical perspectives and overarching research questions. Since we sought to capture digital transformation competencies, the themes *firm-specific* and *general* were first chosen to reflect categories of digital transformation competencies.

In the third step, we used an open coding approach to identify and capture aspects of the data that were of interest and relevance to our research questions. Coding implies organizing the data into meaningful groups (Braun & Clarke, 2006) and collating data extracts for the relevant codes. The applied codes related to the specific competencies that appeared from the data to be relevant to the digital transformation and connected to one of the themes. During the coding exercise, we adjusted the initial themes into four subthemes according to their uniqueness and how the competencies were obtained: *firm-specific (develop), firm-specific (collaborate), general (acquire), general (rent).*

In the fourth step, based on the coding exercise, we gathered and organized all the coded data extracts for each code and accompanying theme. The coded data extracts were studied in detail, with extracts, codes, and themes being reviewed and validated and, sometimes, renamed or recombined. Based on this exercise, we generated a thematic map (Braun & Clarke, 2006). The thematic map was reviewed several times to ensure that we captured the full essence of each theme. Building on our thematic map, we constructed a table to capture the essential employee competencies for digital transformation (see Table 6).

The fifth step involved reviewing and analyzing the findings from the previous steps. We discussed the connections between our findings and the literature and constructed a model to capture how digital transformation competencies could be obtained (Figure 3). In the sixth step we determined the story told by the data and included relevant data extracts in the write-up to capture the points we wanted to demonstrate, illustrated our findings through relevant examples, and related these findings to our research questions (Braun & Clarke, 2006).

4. Results

This section presents our main results. First, we describe GridCo's path toward digital transformation competence. This includes an elaboration of the technological and organizational events that shaped GridCo's digital transformation, leading to the introduction of new technologies and work practices, together with their implications for competency development at GridCo. Second, we present the digital transformation competencies that were identified as essential for GridCo's digital transformation, including how these competencies were obtained.

4.1 The path toward digital transformation competence at GridCo

GridCo had maintained a safe and stable market position for decades, without any need to change. According to an interview respondent, in 2010, "digitalization and talking about digitalization in this company was still very new and unfamiliar. Very unfamiliar!" (Interviewee 45). Recent developments within the grid sector eventually drove GridCo toward digital transformation. In this section, we present some main events and initiatives that shaped GridCo's digital transformation (see Figure 2).

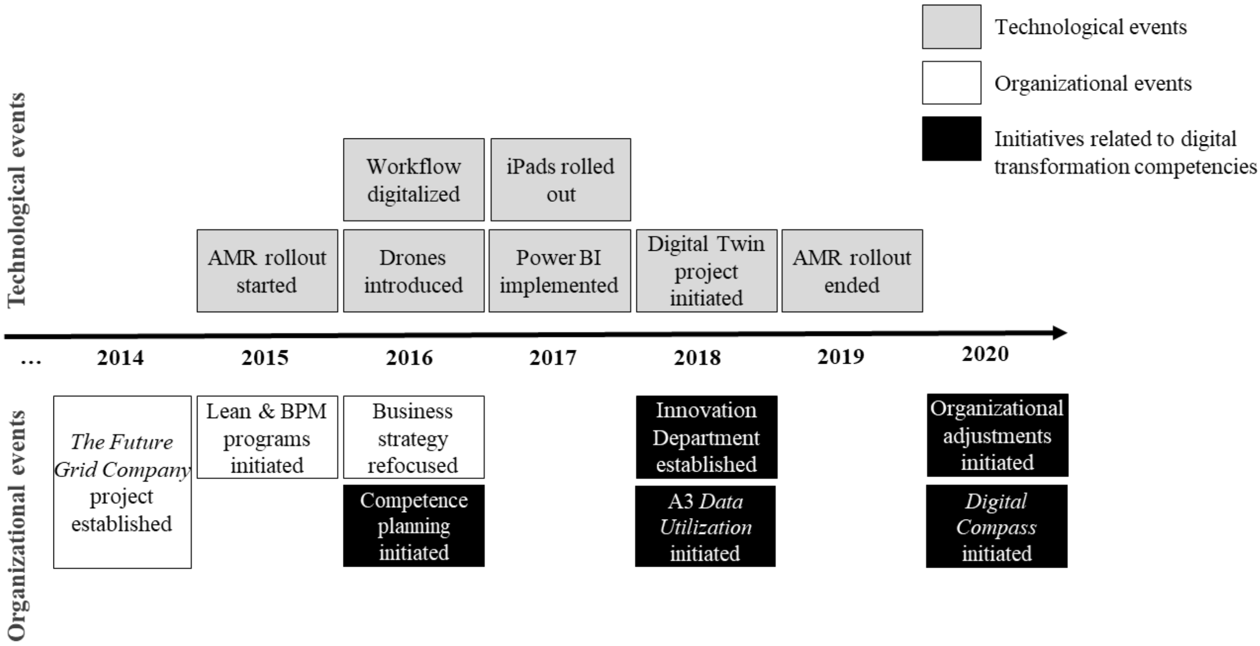

Figure 2. Events in the digital transformation of GridCo

The grey and white boxes in Figure 2 represent technological and organizational events that shaped GridCo's digital transformation. These events involved the introduction of new technologies and changed work practices, which are elaborated in the first subsection. These events, new technologies, and changed work practices had implications for the development of GridCo's digital transformation competence, prompting initiatives to identify and organize digital transformation competencies (black boxes), which are further explained in the second subsection. It is important to note that, in Figure 2, we only included events that appeared from the data to be key from a competence perspective. Internal organizational events (e.g., changes in management positions) and external events (e.g., new industry regulations) were not included in this study. In addition, GridCo experimented with, and invested in, several emerging digital technologies, but for the purpose of this paper, only some examples are presented.

4.1.1 New technologies and work practices

In 2014, GridCo engaged in a project labeled the Future Grid Company, the goal of which was to analyze and establish ways for the company to "improve profitability, better leverage digital technology, and meet the demands and digital trends in the environment" (personal communication, Sept 16, 2018). Although previous initiatives in the organization and events in the environment may also have played a role, this marked the beginning of the digital transformation at GridCo.

The Future Grid Company involved a vision and outlook for GridCo in 2020. To achieve the future-oriented development of the company, one initiative involved changing the ways of working and mindset of the company. Accordingly, in 2015, GridCo introduced a lean approach to working, followed by an increased orientation toward business process management (BPM) in the company. Achieving an overview of company processes, managing these processes, and developing a process-based mindset were important to GridCo because, as one respondent explained: "You cannot achieve a meaningful digital transformation without understanding that it's the processes you are transforming" (Respondent 35).

At the same time, a countrywide rollout of AMR began in late 2015, which represented "the largest sensor upgrade in the grid network ever" (Respondent 36). For GridCo, this necessitated replacing around 240,000 traditional meters with smart meters by January 1, 2019. The implementation of AMR for every household involved incorporating digital elements and smart components into the grid network. AMR technology enabled GridCo to eventually start collecting accurate, real-time data on energy consumption. As stated by GridCo: "AMR technology to collect consumption data and other information on our grid operations provides us with improved knowledge and a foundation for communicating with our customers" (personal communication, Mar 26, 2019). Moreover, the insight and data generated by AMR were perceived as important for GridCo in utilizing the grid network:

> *AMR is not just about meter reading; it's a lot more than that. AMR generates a lot of data that can be used for a lot of different things—things that fall under the term "grid utility". It's important for us to use this data for operational and analytical purposes* (Respondent 33).

In 2016, following the AMR rollout and in line with the ambitions of the Future Grid Company project, a new strategic approach was established, which refocused the business strategy and embraced digital technology and digitalization for the first time. In accordance with the refocused business strategy, GridCo started investing in emerging digital technology, one example of which was drone technology. GridCo acquired its first drone in 2016, increasing the number to seven drones for grid operations in 2018. The drones were mainly used to "assist in searching for faults in the grid, controlling forest cleaning, investigating terrain for the electricians in the field, and evaluating the condition of components in the grid" (personal communication, Dec 20, 2018). According to an internal report on drone usage in GridCo, incorporating drones in the operations had particular benefits for health, safety, and environment (HSE) (e.g., using drones for inspections in dangerous terrain), efficiency (e.g., drones executing fault searches more efficiently than traditional inspections), and customer satisfaction (e.g., drones discovering faults in the grid network before they became apparent).

During 2016, GridCo also developed and implemented a workflow management solution, which involved digitalizing all the workflows and processes preceding and following the physical execution of an electrician's job. The workflow solution was not merely an information system, because it involved a new mindset and new employee interactions. It supported employees in carrying out the processes associated with forecasting, planning, executing, administering, and following up on building, maintaining, and operating components of the grid network. Moreover, the system supported and digitalized processes across GridCo's entire value chain, from customer inquiries to customer satisfaction, and involved new ways of working for the majority of the GridCo workforce.

For the electricians in particular, who made up almost half of the GridCo workforce, the new workflow solution required new ways of interacting. In addition, to support the digitalization, iPads were rolled out to all electricians in 2017, accompanied by a mobile application for the workflow solution. The iPad with the mobile application was intended as a tool for electricians to receive work orders with relevant information, manage their workdays, check off executed work orders, and document their work. Digitalizing the workflow and replacing sticky notes and slow computers with iPads had a great impact on the time electricians spent before and after physically executing a work order; however, the majority of the electricians had limited previous experience of using iPads, and even less with using mobile applications such as the workflow solution. The introduction of the new solution and the iPad tool therefore required the electricians to develop new skills and master new digital technology.

The digitalization and implementation of the workflow solution generated large amounts of data on GridCo's work processes—data the company had never before had access to—but GridCo had limited tools for analyzing and utilizing this data. As one respondent commented: "We had lots and lots of data, and we had good opportunities to sew together some good performance measurements, but we didn't do that" (Respondent 2). Accordingly, GridCo identified a need for a tool that could analyze the increased amounts of data and better measure the company's performance. The Microsoft business intelligence tool Power BI was chosen as a starting point and was implemented in 2017. One manager commented on the value of introducing Power BI in the company:

> *What has changed over the past few years is that data is much more available. Previously, we made decisions based on a "picture" we had—we had a perception of something and we had to spend a lot of time finding the data. Now data is much more available, and we actively use Power BI for decision-making* (Respondent 1).

In 2018, GridCo engaged in another important digitalization project, the purpose of which was to develop a *Digital Twin* (i.e., a "virtual, digital equivalent to a physical product"; Grieves, 2014, p. 1) of the grid network. This project was a collaborative effort, with an external software provider as the project owner responsible for developing the Digital Twin, and GridCo the main user partner. Based on GridCo's data, the project set out to build a Digital Twin of the grid network in GridCo's concession area, with the Digital Twin representing "a simulation of the grid network" (Respondent 36). The Digital

Twin was intended to prepare GridCo for emerging digital challenges in a profitable and efficient manner, in order to initiate modern, future-oriented grid initiatives and utilize and share data more efficiently. Accordingly, the Digital Twin was eventually considered to be an important building block for GridCo's digital transformation.

4.1.2 Implications for competence development

Over time, it became clear to the GridCo management team that they did not have sufficient workforce competence to support the digital transformation and the visions of the Future Grid Company; hence a shift in competence was necessary. Accordingly, to support the digital transformation efforts, GridCo established a routine for competence planning early in 2016. This involved the management team adjusting the company's strategic competence plan twice a year. The aim of the competence planning was to determine how the company could ensure the right competencies to support existing and future business in the short and medium term. The plan incorporated existing organizational competencies and future competency needs across the entire organization.

To support the ongoing digitalization initiatives, new digital technologies, and increased amounts of data, GridCo established an Innovation Department in 2018. The Department was founded to manage and oversee processes relating to innovation, strategy development, and digitalization, among other issues. A central role of the Innovation Department was to support GridCo in identifying new competency requirements following the digital transformation and to function as a hub for organizing newly obtained digital transformation competence. In 2018, the Innovation Department also developed a strategy A3 labeled *Data Utilization.* A strategy A3 is a problem-solving tool from the lean toolbox, which helps companies to state the current situation and the problems to be solved, highlight goals, propose and plan appropriate measures, and follow up to ensure that targets are reached. The Data Utilization A3 incorporated several aspects of digital business development and determined how to utilize increased amounts of data. The A3 incorporated objectives, such as having access to all relevant data, an overview of all existing and potential data sources, and increased quality and completeness of data. In addition, the A3's stated aim was to enhance GridCo's ability to "make decisions based on data, before faults happen" (prediction) and allow "data to be updated in real-time where necessary" (personal communication, Dec 12, 2020). Digital transformation competence was also a major part of the A3. In conjunction with the work on competence planning, one main contribution of the A3 was identifying the competencies necessary to utilize increasing amounts of data.

Because the Future Grid Company project involved GridCo's vision up to 2020, a revision was necessary for 2020 onwards. Accordingly, new initiatives to set GridCo's future directions were introduced in 2020, which had (and will continue to have) implications for the competence base moving forward. First, some organizational adjustments were initiated in April 2020 to better utilize the newly obtained digital transformation competencies and prepare for further competence development; for instance, the employees with digital technology expertise were grouped into one department to ease collaboration and peer learning. Second, the company implemented the Digital Compass—an extensive digital transformation program to guide the further digital transformation of GridCo. The program was established during the spring of 2020 in cooperation with an external partner, with the aim of setting a direction for the continued digital transformation and embracing the "technology applications and data utilization necessary for achieving [GridCo's] strategic aims" (personal communication, Mar 2, 2020). During the development of the Digital Compass, the Digital Twin was evaluated as an important element in the program and an essential building block for GridCo's continued digital transformation. The Digital Compass had several dimensions, including competence management and development. The direction that the Digital Compass set for GridCo would require new and improved company capabilities and employee competencies.

4.2 Digital transformation competencies at GridCo

The competence initiatives throughout the digital transformation collectively provided GridCo with relevant insight into the company's current competence, as well as the competence needed to embrace the digital transformation. This resulted in what GridCo refers to as a "competence shift" in the company, which involved "the competence base within electrical power engineering [being] supplemented with competence in digital technology" (personal communication, Mar 14, 2019). This competence shift was expected to underlie the competence planning in the future and affect the entire organization. As one respondent commented:

> *Everything regarding data and technology is exploding now—for us, as for everyone else. A shift is happening, which is enormous, and which we definitely haven't seen the end of, but we have started that journey and are recruiting quite a lot of new competent employees. We are adding new competencies that we haven't had before, and a lot more is happening on the competence front—now more than ever* (Respondent 33).

We identified 14 digital transformation competencies in this study (summarized in Table 6), which we assigned to two main categories, depending on a competency's' uniqueness (firm-specific or general). We further divided these categories into four subcategories, according to how the competencies were obtained at GridCo.

Table 6. Digital transformation competencies

A: Firm-specific digital transformation competencies	B: General digital transformation competencies
A1: Develop	**B1: Acquire**
• Digital technology orientation • Digital technology adoption • Specific digital technology expertise • Specific analytical skills • Industry-specific analytics • Process improvement & digitalization	• General digital technology expertise • General analytical skills • Data management skills • Portfolio management skills • Agile project management skills
A2: Collaborate	**B2: Rent**
• Unique digitalization-project competence	• Digitization competence • General analytical support

The digital transformation competencies identified in this study reflect competencies necessary for GridCo's digital transformation by which they did not possess in their existing competence base, and encompass knowledge, skills, and abilities of employees across the entire organization (both IS professionals and non-IS professionals). GridCo obtained digital transformation competencies through a combination of four approaches: develop, collaborate, acquire, or rent. In the following subsection, we elaborate on the four subcategories of digital transformation competencies.

4.2.1 Developing firm-specific digital transformation competencies (A1)

The first category involved competencies that were of particular relevance for GridCo's digital transformation, but were not necessarily readily available in the market. Furthermore, since GridCo were certain they needed these competencies for their digital transformation, they wanted to retain the competencies within the firm. Accordingly, the approach chosen to obtain this type of competency was to develop the competencies internally. This involved GridCo facilitating skill development and knowledge sharing by supporting continuing education, offering relevant training courses, encouraging self and peer learning, providing opportunities to attend external seminars, and involving employees in digitalization projects.

Since the new workflow solution and the use of iPads for work was unfamiliar to the majority of electricians, the company offered training to develop *digital technology orientation* and *digital technology adoption* among electricians. Digital technology orientation refers, not only to the willingness and capacity to use digital technology, but also the general awareness of, and interest in, digital technology that can lead to a digitally enabled workforce (Alam et al., 2018). Digital technology adoption refers to the application of digital technology and occurs when employees realize or decide that the digital technology has utility, adding value to their work and tasks (Alam et al., 2018); however, as pointed out by several interviewees, the first training provided was not well received by employees. Large groups, general content, and poor individual customization led to frustration and limited learning for electricians. One interview respondent emphasized this:

> *They gathered a lot of people together and then they rushed through it. The electricians were present, but they could have talked about whatever, and they wouldn't have remembered*

anything anyway. Training is crucial. You have to get people on board, even those who resist. It's mostly just about them not understanding [the technology], and being insecure about using it (Respondent 10).

After receiving feedback from the employees, the company revised and improved the training approach. GridCo started offering more thorough and customized training sessions, in smaller groups, to meet the different needs and demands of the electricians. As one interviewee commented, "tutoring videos are now published regularly to help explain specific issues raised by users" (Respondent 5).

For some digital technology, GridCo saw the need to develop more explicit competence; what we termed *specific digital technology expertise*. This involved developing competence in using digital technology that would be specifically applied within the GridCo context (i.e., where the employees gaining competence would also require knowledge of the company's processes and tasks in order for the technology applications to be of value). Some examples of these digital technology applications were AMR technology and drones. To manage the increased application of drones in grid operations, and to comply with the company's and grid sector's high HSE standards, GridCo trained a number of electricians to become drone pilots. By autumn 2018, GridCo had trained 24 RO1 pilots and one RO2[2] pilot. The electricians trained to become drone pilots were handpicked by the operations managers based on the electricians' interests and areas of expertise (aerial line vs. underground cable), locations, and shift affiliations. Regarding AMR, the rollout meant that the electricians in the field had to manage a new type of electric meter when executing jobs in private households. The electrical engineering competence required of the electricians remained the same, but the competence required to fixing defective meters or faulty AMR readings had changed to include more automation, which was something "not all electricians had the competence to manage" (Respondent 24). Accordingly, training was necessary to ensure that the electricians developed this competency. One respondent explained:

Previously all electricians could fix [defective meters], but now we have replaced all those meters. Some of the AMR meters will have faults, and then the AMR component needs to be replaced with a new one, which is an entirely different competency (Respondent 2).

GridCo also identified *specific analytical skills* as a necessary competency for their digital transformation (i.e., the skills to perform company-specific analyses), and GridCo decided to develop

[2] RO = Remotely Piloted Aircraft Systems Operator. RO1: for flying drones up to 2.5 kg, including cargo, up to 60 knots. RO2: for flying drones up to 25 kg, including cargo, up to 80 knot.

this competence internally. In particular, GridCo needed people with strong analytical skills to measure and monitor grid and process performance, enabling the management team to make better, data-driven decisions. This was important because, as one respondent pointed out, performance analysis and measurement were limited at GridCo: “Measuring and planning were based on guesswork— not on actual data. It’s like navigating based on the route of a ship—you look over your shoulder to see how you managed” (Respondent 13). The digitalization of workflows and the implementation of the workflow solution generated new and increased data on company processes. Furthermore, when Power BI was introduced as a tool for company process analytics, competence was required to master the tool and analyze and utilize the increased amounts of process data. Accordingly, 2–3 employees who had shown a specific interest were asked to allocate some of their workday to learning the tool. These employees were extremely knowledgeable about the company processes, had a higher than average interest in digital technology, and recognized how it could improve their work, but they had no formal IS technical background. In due course, the employees mastered the tool and developed analyses and reports, on request, for managers across the entire company. This development was highly appreciated by managers at different levels. As one manager stated:

> *Now, with Power BI, if you just come up with the right questions, they put together reports and BAM! Everything I know today [about my department’s processes and performance], I know because they have produced some Power BI reports. I can go in and make adjustments and, suddenly, a picture of what is actually happening in the business becomes available in digital format. You gain a whole other level of management information, and now we are all starting to have the same picture and understanding of which employees we have and how productive we are* (Respondent 2).

The Power BI example illustrates GridCo’s encouragement of self-learning. The company also realized they had a lot to learn from other companies and from each other; for instance, traditionally, only managers attended external seminars and conferences. More recently, however, GridCo acknowledged the value of operational employees, in addition to managers, attending such events—to gain insight into the opportunities to use digital technology and data to improve processes, products, and services. As an example, in 2018, five employees from different departments attended a conference in London on grid analytics (i.e., *industry-specific analytics*) and were thus exposed to the latest digital innovations and solutions within the grid sector. The employees, who worked with processes on a daily basis, came back to the company glowing and inspired, with plenty of fresh ideas for how GridCo could use digital technology to improve its processes and services. On their return, they shared their thoughts and ideas with management and colleagues on several occasions. This was an example of both learning from external others and learning from each other. Furthermore, letting employees, rather than managers, have this kind of experience sent a positive signal to all employees, helping to build a digital culture. A typical arena for this type of sharing and learning was what GridCo called Competence Hours: bi-monthly sessions during which one or more employees shared specific insights and competence with others.

GridCo initiated several *process improvement and digitalization* efforts in their digital transformation. The development and implementation of the workflow solution represented both process improvement and digitalization and was organized in a way that enabled employees to be "involved throughout the process in different roles, to ensure acceptance of the implementation and a user-friendly solution" (personal communication, Nov 5, 2018). Accordingly, employees from the business units (not merely the IT function) were involved in the digitalization effort, which increased their competencies in process improvement and digitalization. The workflow solution was further continuously improved based on feedback and input from employees, ensuring that the solution would actually accommodate the employees' needs. The success of the workflow solution inspired GridCo to continue to involve employees in digitalization efforts from then onward—which in turn would increase employee competence in process improvement and digitalization. An internal report on the workflow solution project emphasized employee involvement as a key take-away for future digitalization projects:

> *Involve the operational employees continuously in the project and in the steering committee to ensure the solutions accommodate the users' needs. Test the solution and involve the users to achieve good results and reduce resistance. Involvement is necessary for the project to understand user needs and achieve a unified understanding of why change is necessary and how the project is necessary to achieve company goals* (personal communication, Nov 5, 2018).

In addition, GridCo established what they called the Digitalization Promise—an interactive training and sharing platform on the company intranet. As stated by the management: "The Digitalization Promise is an internal program of three modules, which aims to increase our common consciousness on digitalization" (personal communication, Nov 14, 2018). On the platform, employees were also encouraged to share their digitalization experiences and thoughts on the topic. They even arranged a competition, with the winner drawn from among those who had shared their experience, and the prize was a drone.

4.2.2 Collaborating for firm-specific digital transformation competencies (A2)

The second category involved competencies that were considered specific to GridCo, but were unfamiliar to the company, and GridCo was uncertain of the necessity of the competencies for their digital transformation. Because of the unique, unfamiliar, and uncertain nature of this type of competence, GridCo decided to collaborate with external parties to obtain it.

We included *unique digitalization-project competence* in this category—competence relating to specific GridCo digitalization projects. For GridCo, this covered competence relating to the Digital Twin project and particular knowledge about, and skills in, simulation. To obtain this competence, GridCo engaged in collaboration with an external company that could provide simulation expertise. As one interview respondent commented: "We have the domain knowledge, and they are very good at simulation" (Respondent 36). Initially, GridCo was uncertain of the value of this competence for their digital transformation; however, as they gradually came to understand the competence and its relevance, as well as the Digital Twin and its potential areas of application, the uncertainty faded. This also related to how the Digital Twin, over time, evolved to become an important building block in the Digital Compass and overall digital transformation at GridCo. Taking part in the Digital Twin project was a learning process for GridCo, with simulation competence being incrementally transferred to GridCo. As one manager commented, "Being part of the [Digital Twin] project has developed our knowledge and matured us as a company" (Respondent 34).

4.2.3 Acquiring general digital transformation competencies (B1)

The third category involved general competencies in which GridCo was certain it needed for its digital transformation, sooner rather than later. Because GridCo was confident it needed these competencies for its digital transformation, it wanted to retain the competencies in-house; however, because this type of competence was available in the market, GridCo decided to acquire these competencies. This involved GridCo recruiting people who had the competencies that were relevant and necessary for its digital transformation—typically people with knowledge and skills that were new to GridCo.

As several new digital technologies were introduced during GridCo's digital transformation, GridCo identified a need to obtain *general digital technology expertise*. In particular, the competence plans highlighted expertise within areas such as robotization, machine learning, sensor technology, and big data. As an example, in January 2019, GridCo hired two data scientists. Their main tasks consisted of applying their expertise to find ways to better utilize the massive amounts of data available to the company, and to experiment with machine learning. This was important for GridCo to be able to utilize the increased amounts of real-time data generated by AMR and other sensor technology.

In addition, building on the initiated Power BI and specific analytical efforts, GridCo saw a need to strengthen *general analytical skills* in the company and hired a BI developer in April 2019. The company reasoned that the Power BI analyses had become important for measuring performance; however, the work lacked structure and had limited scalability. The company therefore acquired external competence in BI development, to improve business intelligence in the company and "to build more specialized competence, to be able to use the data in a better way, to visualize data better, and to have a bit more control" (Respondent 30).

Despite obtaining general digital technology expertise and general analytical skills, GridCo still acknowledged its limited knowledge of the data that was available and how this data could be used; therefore, the company decided to acquire competence in *data management*. Accordingly, a master data management (MDM) advisor was recruited in September 2019. His main task was to establish a structure for how data was gathered, stored, and applied, and to take the necessary measures to increase data completeness and quality across the organization.

GridCo was, as mentioned, engaged in several digitalization efforts in its digital transformation, from small day-to-day improvements to large research and development (R&D) projects in collaboration with external parties. As the number of such initiatives increased, the management team felt it was losing control of them. The company saw the need for competence in *portfolio management*, to improve the structures and processes of the company's digitalization and R&D projects. Accordingly, a portfolio manager was recruited in January 2019. He built a framework for prioritizing projects, based on criteria such as strategic fit, feasibility (plan, resources, complexity, and uncertainty), and profit potential. As a result, company policy eventually stated that "no project (over a certain cost limit) is to be initiated without passing through the portfolio funnel" (personal communication, Dec 13, 2019).

Digitalization efforts and projects at GridCo often moved slowly. To deal with the slow pace, the company needed to develop competence in *agile project management* and recruited a scrum master in January 2019. The scrum master introduced sprints (an agile project management concept), by which certain tasks or activities would be completed within a set period. Sprints were introduced to enable and accelerate change initiatives in the company, "to be able to deliver solutions quicker" (Respondent 42), "through focused and systematic work in dedicated and multidisciplinary teams" (personal communication, May 20, 2019).

4.2.4 Renting general digital transformation competencies (B2)

The fourth category involved competencies that were general and available in the market, but which GridCo was uncertain of the value of for the digital transformation, as well as how many, and for how long, competencies would be necessary. Because of the uncertainty, GridCo decided to rent this type of competence from the external environment, mainly through temporary employment.

One example of this approach was *digitization competence*. Digitization involves encoding analog information in a digital format (Yoo, Lyytinen, et al., 2010). In particular, GridCo realized a need to digitize their archive as part of the digital transformation. The company had a long tradition of building and expanding the grid network, with accompanying documentation (e.g., contracts, maps, drawings, and technical component specifications) stored in a physical archive in the basement, which in some cases was more than 100 years old. To collate and utilize all the available data, GridCo needed to digitize these huge amounts of data. Competence in doing this was readily available in the market, but because of uncertainty surrounding the necessity of the competence and how long the digitization work would take, GridCo did not want to acquire the competence and retain it. Instead, students were engaged on temporary contracts to carry out this digitizing work.

A second competence that GridCo rented temporarily was what we termed *general analytical support.* In particular, as increasing amounts of drones were used in the operations, it became clear that the data generated by the drones was neither well-structured nor fully utilized. To overcome this challenge, GridCo recruited university students as summer interns to support GridCo by processing and analyzing data (e.g., images and videos) from the drones and experimenting with image recognition. The interns' approach was thoroughly documented and the competence they gained was transferred to the organization after their engagement was completed.

5. Discussion

We now return to our research questions. In the following, we seek to generalize our results to provide insight to other incumbent firms in their digital transformations. Our first research question concerned the competencies that are essential for digital transformation. We identified 14 digital transformation competencies in our study, which were either firm-specific (category A) or general (category B).

5.1 Firm-specific digital transformation competencies

These competencies are considered to be unique and specific to a particular firm's digital transformation. Although our findings focused on competencies that were specific to GridCo, insights from our findings may very well be transferable to other incumbent firms and other industries; for instance, digital technology orientation and digital technology adoption are considered to be firm-specific because they relate to firm-specific technology and processes, which naturally differ between firms. Nonetheless, we believe that ensuring employees' digital technology orientation and digital technology adoption is crucial for any firm's digital transformation. Specific digital technology expertise and specific analytical skills also fall into this category—expertise and skills that are particularly linked to the idiosyncrasy of the firm. In a similar vein, although not entirely firm-specific, we also included industry-specific analytics in this category. The grid sector is rather limited in Norway and, hence, grid-specific competencies are unique and not readily available in the market. This could apply to other firms as well, depending on the industry in which they operate. Competencies in process improvement and digitalization also fall into this category, since they depend on knowledge of a firm's processes, tasks, systems, roles, and interactions—and are therefore difficult to obtain outside a firm's boundaries. Finally, unique digitalization-project competence falls into this category, involving competencies unique for specific digitalization projects. Depending on a firm's digitalization projects and the aims of its digital transformation, the specifics of this competence will vary between firms; however, in general, any firm investing in digitalization projects should consider which competencies they lack but need for the project to succeed and contribute to the overall digital transformation.

5.2 General digital transformation competencies

These competencies are not unique to a firm, since they are typically acquired through education and are readily available in the market. Within this category we identified general expertise in digital technology and general analytical skills, in line with prevailing research (e.g., Dremel et al., 2017; Kettunen & Laanti, 2017; Khin & Ho, 2018). Competence in data management also falls into this category but does not seem to have received much attention in the digital transformation literature, perhaps because data management is often considered to be an integral part of data analysis and is therefore not viewed as a separate skill or competency. In the case of GridCo, however, data management was seen as a particularly crucial prerequisite for data analysis, in view of the increased amounts of data; thus, data management was included as a separate general competence essential for digital transformation. In line with Andriole (2018) and Butschan and colleagues (2019), portfolio management and agile project management fell into this category, which also included other general digital transformation competencies, such as digitization and general analytical support, which may be less strategically important, but should not be ignored.

5.3 Approaches for obtaining digital transformation competencies

Our second research question considered how incumbent firms could obtain digital transformation competencies. In our study, we found four main approaches for obtaining digital transformation competencies: develop, acquire, rent, or collaborate. Based on our findings and the prevailing literature, we argue that the appropriateness of an approach for incumbent firms' digital transformations will vary, depending on the uniqueness and uncertainty of the competency requirement. Inspired by Lepak and Snell's (1999) human resources (HR) architecture model, we developed a generic model for obtaining digital transformation competencies, as illustrated in Figure 3.

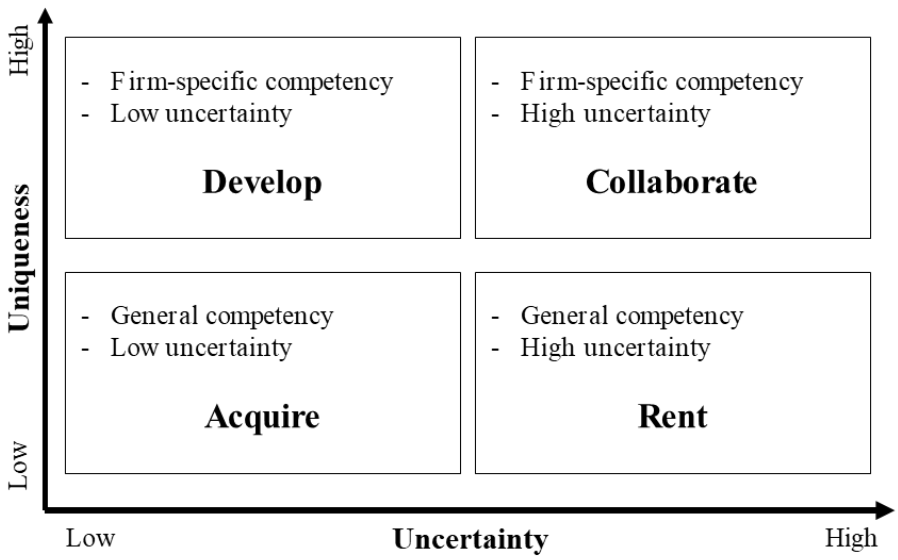

Figure 3. Obtaining digital transformation competencies (inspired by Lepak & Snell [1999])

In our model, we kept the original uniqueness dimension of Lepak and Snell (1999) to refer to the competency's level of firm-specificity (Lepak & Snell, 1999), which is often linked to the competency's relationship to the firm's processes and firm-specific technology (Barney & Wright, 1998), as well as the degree of social complexity (Lepak & Snell, 1999; Nordhaug & Grønhaug; 1994) and level of tacitness (Polanyi, 1967) of the knowledge underlying the competency. To adapt the model to a digital transformation perspective, reflecting the uncertain nature of digital transformations, we replaced the value dimension of Lepak and Snell (1999) with an uncertainty dimension, referring to the level of uncertainty surrounding either the value of the competency for the digital transformation or the duration or volume for which the competency is needed, if at all.

Developing competence is a suitable approach for obtaining firm-specific digital transformation competencies (Lepak & Snell, 1999; Nordhaug & Grønhaug, 1994) in situations where the uncertainty regarding the need for competence is low. This relates to competence that is linked to the idiosyncrasy of the firm and which the firm is certain is necessary for its digital transformation. For the competence to align with the company's processes, the competence should be developed internally, which requires firms to provide effective training (Dremel et al., 2017; Kensbock & Stöckmann, 2020; Khin & Ho, 2018). As employees often have an innate tendency to learn, firms should foster and utilize existing workforce' learning motivation (Kensbock & Stöckmann, 2020). This could include establishing a skill-building unit (Khin & Ho, 2018), ensuring that employees have access to relevant resources to support the technology and its application (Larsson-Lund & Nyman, 2020), and encouraging and motivating the self-learning and competency development of employees (Mueller & Renken, 2017), as well as peer-learning (Kensbock & Stöckmann, 2020).

If the digital transformation competence is firm-specific, but the level of uncertainty is high, collaboration with external parties is a suitable approach for obtaining the relevant competencies. This would typically be the case for the competence needed to master tasks that are hard to specify or particularly unique (e.g., in relation to specific digitalization projects). In such cases, a collaborative approach that enables firms to build on other parties' expertise would be appropriate: firms could engage with specialized consultancies (Dremel et al., 2017), or enter into collaboration or alliances with strong players in the environment (Khin & Ho, 2018; Lepak & Snell, 1999). Using a collaborative approach, firms can interact with other parties who share the same objectives, while avoiding the risk of significant investments in competency development under high levels of uncertainty. A collaborative approach contributes to learning across company borders, and the synergistic value realized by the collaborators may exceed the value that a single firm could achieve independently (Lepak & Snell, 1999).

Acquiring digital transformation competencies is an applicable approach for competence that is general and involves low uncertainty; in other words, this approach is suitable for obtaining competencies that the firm is certain they need for their digital transformation, but which they do not have the time or ability to develop internally. General competencies are typically readily available in the market (Barney & Wright, 1998; Nordhaug & Grønhaug, 1994). By acquiring them, the firm can benefit from valuable competencies that have been developed elsewhere and retain them internally (Lepak & Snell, 1999). This typically involves recruiting people with professional knowledge and skills that are new or unfamiliar to the firm, which are often developed through education or require time and experience to develop. However, it is important to note that this option is often difficult in practice, given that digital talent is a scarce source in many countries (Grundke et al., 2018) by which many firms are competing for (Kensbock & Stöckmann, 2020).

Renting digital transformation competencies should be the chosen approach if the competence is general and if the level of uncertainty is high. This approach is similar to the acquire approach, but applies to situations where the duration and extent of the required competence is uncertain, or the firm is uncertain about the competency's contribution to the firm's overall digital transformation. In such cases, a renting approach provides the flexibility needed to deal with the high levels of uncertainty. A renting approach typically involves contract work, such as temporary employment or employee leasing arrangements (Andriole, 2018; Lepak & Snell, 1999).

In addition to the above, our study revealed four concrete measures that are important for managers to consider when identifying, obtaining, developing, utilizing, and maintaining digital transformation competencies:

Mobilize current competencies. Before taking any measures to obtain digital transformation competencies, firms should evaluate and consider possibilities for mobilizing (Alexander & Lyytinen, 2017) current internal competencies. Perhaps an employee enjoys programming as a hobby and their skills could be better utilized if they were given other tasks or assigned to a different department. Such insight requires thorough mapping and understanding of current competencies, beyond merely the level of education and previous work history. It requires listening carefully to employees to uncover their undocumented skills, interests, experiences, attitudes, and similar. This relates to the notion of competence visibility (Nordhaug & Grønhaug, 1994), which considers whether firm's competencies are being used or remain hidden or untapped. If competencies are not applied, they are of limited value to firms (Nordhaug & Grønhaug, 1994). Competencies should be identified through individual development plans and frequent dialogs with employees, supported by appropriate HR competency management and training systems (Barney & Wright, 1998).

Build and nurture a digital culture. Creating an appropriate and supportive digital culture is essential for achieving successful digital transformation (Fitzgerald et al., 2014; Hartl & Hess, 2017; Kozanoglu & Abedin, 2020; Mueller & Renken, 2017). Without a digital culture, digital talent will not remain with the firm (Lee et al., 2017). Accordingly, firms should build and nurture a digital culture, supporting employees in maintaining and developing digital transformation competencies. This implies integrating digital cultural values, such as openness to change, customer centricity, innovation, agility, trust, and risk affinity (Hartl & Hess, 2017). Moreover, firms should adopt a digital culture that encourages employees to be proactive and independent and take part in discussions and decisions, where mistakes are tolerated, knowledge and information are shared, and collaboration is encouraged (Hartl & Hess, 2017). Finally, a digital culture involves the firm fostering learning (Kensbok & Stöckmann, 2020) and continuously ensuring relevant competencies for continued digital transformation (Hartl & Hess, 2017).

Develop and restructure the organization. Obtaining new digital transformation competencies will change the competence bases of firms and may require some organizational restructuring. According to Dremel and colleagues (2017), an important stage in a digital transformation involves leveraging the newly added competencies in the firm. One approach is to make organizational adjustments, adapted to the digital age, to better accommodate the new competence base, which could involve developing competence centers and ensuring clearly defined roles and responsibilities (Dremel et al., 2017). At GridCo, the establishment of the Innovation Department represented such an effort to build relevant expertise and skills in an organized way. Adding roles such as scrum master and portfolio manager also reflected the company's measures to oversee, organize, and approach the initiatives underlying the digital transformation. Furthermore, the grouping of employees with certain digital transformation competencies facilitated better utilization of these combined competencies. Combining digital transformation competencies can create synergies and generate better results than utilizing competencies individually (Nordhaug & Grønhaug, 1994).

Protect and develop competencies. It is not enough to obtain digital transformation competence. Once the competencies are in place, firms need to efficiently protect the competence base (Nordhaug & Grønhaug, 1994) and simultaneously continue to develop competencies (Alexander & Lyytinen, 2017; Kensbock & Stöckmann, 2020). To accomplish this, firms should continue to nurture a digital culture, ensure that the necessary support and resources are in place, offer challenging tasks, and encourage a work environment characterized by continuous learning (Kensbock & Stöckmann, 2020) and experimentation. Management teams and HR functions play an important role (Barney & Wright, 1998) in establishing appropriate practices (Kensbock & Stöckmann, 2020) for ensuring, protecting, and developing right and relevant competencies.

5.4 Contributions

Our study has several implications for research. We have contributed to the IS literature by exploring competencies from a digital transformation perspective. Our conceptual model (Figure 1) should help to delineate and clarify the relationships and differences between digital transformation capabilities and digital transformation competencies. We identified key competencies for incumbent firms that are embracing digital transformation (Table 6). The competencies identified in this study encompass knowledge, skills, and abilities among employees across the entire organization, thereby expanding the focus in prevailing IS literature, which has mainly revolved around managers and IS professionals. Furthermore, we provided a generic model for obtaining digital transformation competencies, depending on the competencies' levels of uniqueness and uncertainty (Figure 3), which can applied, tested and developed further in future research. Our research therefore provides valuable insights and steps for achieving a better understanding of digital transformation and ways for incumbent firms to accomplish such transformations.

Our research also has implications for practice. Prevailing research has found that several incumbent firms lack competencies to succeed in their digital transformation (Kensbock & Stöckmann, 2020). Our study provides managers and HR practitioners with examples of the competencies that could be essential in their digital transformations and how these might best be obtained. We have also highlighted some important measures to be considered when identifying, obtaining, developing, utilizing, and maintaining digital transformation competencies. Our research provides valuable insights for practitioners embarking on digital transformations.

5.5 Limitations and outlook for future research

There are some limitations to our research. The digital transformation competencies identified in this study were derived from a single case study, and we acknowledge that digital transformation competencies, particularly those that are firm-specific, will vary somewhat across firms and industries (Khin & Ho, 2018). We have tried to capture and conceptualize each digital transformation competency on a general level, so that the insights drawn from this study can be transferred to other contexts; nevertheless, further research investigating digital transformation competencies in other firms is necessary to increase our understanding of digital transformation competence. In addition, the focus in this paper was on IS-related competencies—future research could include other organizational competencies and integrate findings from other research fields to enrichen our findings.

Digital transformation is a continuous and uncertain process, often without a clear beginning or end. The findings of this study identified competencies that were considered to be necessary for GridCo's digital transformation up to the time of this study and in the near future, but the company will continue its approach to competency planning. As new digital solutions arise, and employees become more familiar with digital technologies, GridCo will probably identify new competence gaps. Furthermore, developments in the grid sector, and business model changes, are likely to lead to new service offerings and tasks, which will affect the competency requirements for embracing continued digital transformation. Since competence requirements are subject to change across different stages (Kræmmergaard & Rose, 2002) of a digital transformation process, it would be valuable to study changes in competency requirements for a longer period, across different stages of the digital transformation process.

Our study investigated digital transformation competencies nested in the employee level; however, prevailing research has showed that the roles of managers and executives are important in a firm's digital transformation (Chanias et al., 2019; Haffke et al., 2016; Matt et al., 2015; Singh & Hess, 2017; Singh et al., 2020). Accordingly, investigating higher-level competencies would be a promising avenue for future research. Managers also play a crucial role in identifying, planning, and obtaining competencies (Barney & Wright, 1998; Nordhaug & Grønhaug, 1994). As firms increasingly comprise of individuals with different and new digital transformation competencies, coordinating and utilizing "a range of dissimilar competences that are spread among a large number of employees" (Nordhaug & Grønhaug, 1994, p. 92) presents a challenge. Future research should look deeper into how management could best address this challenge.

Another fruitful avenue for future research would be to investigate digital transformation competencies in teams or networks. We know from previous research that combining competencies through cooperation can create synergies and generate better results than utilizing competencies individually, and that competence has a social dimension (Nordhaug & Grønhaug, 1994); hence, individual digital transformation competencies may increase in value when used in collaboration with others, and future research could investigate competency configurations in teams or networks to enrich our understanding of digital transformation competence.

6. Concluding remarks

Digital transformations require incumbent firms to rethink their competence bases; however, research is limited regarding the employee competencies that are particularly important for incumbent firms' digital transformations. To contribute to reducing this gap, we conceptualized digital transformation competence and empirically investigated two research questions: (1) which competencies are essential for digital transformations and (2) how can incumbent firms obtain digital transformation competencies? To address these questions, we conducted a longitudinal case study of a Norwegian grid company undergoing a digital transformation and uncovered a shift in competence requirements following their digital transformation. We identified four categories of digital transformation competencies (i.e., competencies that are essential for a firm's digital transformation). Furthermore, inspired by Lepak and Snell's (1999) HR architecture model, we developed a generic model that can be used to determine appropriate approaches for obtaining digital transformation competencies. Our research contributes to both research and practice by unpacking the concept of digital transformation competence, thereby increasing our common understanding of what digital transformation entails and how incumbent firms should embrace digital transformation.

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Article 2

Title: Making sense of continuous development of digital infrastructures

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Abstract: Continuous development extends the agile approach and focuses on bringing valuable services to users, on demand or by intention, in patterns or series, with the aim of achieving a continuous flow of learning and development in short cycles. The objective of this work is to theorize the idea of continuous development in the context of digital infrastructure evolution and explore the forces of the phenomenon. By drawing on literature on digital infrastructure theory and continuous development as it has emerged as an idea from the DevOps thinking expanded from agile, we outline main characteristics of continuous development and propose a theoretical definition of continuous development in organizational contexts. Then, in answering our research question 'which patterns of interactions can be identified in the continuous development of digital infrastructures?', we conducted a longitudinal case study at a Norwegian grid company and explored how a specific digital infrastructure evolved through continuous development. We identified generic interaction patterns with two cycles of sense-giving and sense-making between organizational actors, enabling the continuous development of the digital infrastructure. Our findings and model of interaction patterns offer a nuanced perspective on both digital infrastructure evolution and established perspectives of sense-making and sense-giving mechanisms, as well as new ways to think about digitalization in incumbent firms.

Keywords: continuous development, digital infrastructure, sense-making, sense-giving, digitalization, incumbent firms

1. Introduction

It is a striking trend how concepts and ideas from the IT world increasingly influence the business and public discourses. The most prominent examples are *platforms* and *ecosystems*, which both have become household terms used in several contexts. Another example is *agile*, which denoted a fast, iterative, and incremental method to develop software (Beck *et al.*, 2001), but which later became a key approach to entrepreneurship and startups (Ries, 2011) and then to corporate practices (Fitzgerald and Stol, 2017) in aiming to improve innovation cycles (Holbeche, 2018). The trend illustrates the increasing importance of digital technologies, but also the innovative power of the information systems (IS) community. Around 2010 an extension of agile was introduced; *DevOps*, which integrated both the business case and the operations function in development processes and focused on continuous delivery of new services (not only software) (Humble and Molesky, 2011; Ebert *et al.*, 2016). This implied that DevOps teams had to relate closely to both business services and the existing and running IT solutions, as each new service would extend the existing digital infrastructure (Wiedemann *et al.*, 2019). Because DevOps focused on activities such as continuous integration and continuous delivery, the concept *continuous development* emerged as an umbrella term (Fitzgerald and Stol, 2017; Rodríguez *et al.*, 2017; Fassbinder, 2019)—a term by which Google today returns 3.9 million hits. However, emerging from practice (as did agile), IS research exploring the underpinnings of continuous development is still nascent (Hemon *et al.*, 2020).

Continuous change and development is not a new idea—it has been described as an alternative to punctuated equilibrium models (Brown and Eisenhardt, 1997) and project based approaches that assume alternations of periods of change and stability (Humble and Molesky, 2011). It is also an emerging term within software development (Rodríguez *et al.*, 2017; Fassbinder, 2019). In 2018, Bussgang and Clemens (2018) published an article in Harvard Business Review titled "Continuous Development Will Change Organizations as Much as Agile Did". The authors argued that continuous development, used as a business approach, offers four key benefits: it decreases time to market, allows for more frequent experimentation, enables faster problem resolution, and leads to greater productivity.

Bussgang and Clemens' (2018) conceptualization described continuous development as an organizational concept, and not a technical one. The question then is, what is being developed? It is not the organization, as such, being developed. Rather, so we argue, it is the organizations' digital infrastructures (i.e., socio-technical networks of technology and users; Hanseth and Lyytinen, 2010) being developed, through incremental innovation, learning, and quick user feedback. Continuous development focuses on bringing valuable services to users, on demand or by intention, in patterns or series, with the aim of achieving a continuous flow of learning and development in short cycles (Rodríguez *et al.*, 2017). An early example of this conceptualization is Iyer and Davenport's (2008) description of how Google innovates and expands its digital infrastructure service by service. Following Bussgang and Clemens' (2018) recommendations, the ambition of this article is to theorize the concept of continuous development in the context of digital infrastructure evolution, and to explore the forces of the phenomenon.

To do so, we first reviewed relevant literature on digital infrastructure evolution, as well as literature on agile development and DevOps to explore the roots of continuous development. Based on the literature we outlined main characteristics and suggested a definition of continuous development of digital infrastructures. Whereas the unit of analysis of agile processes typically has been the development team (i.e., team level)—which was expanded with DevOps to also integrate the operations function (still team level)—considering continuous development in the context of digital infrastructure evolution implies expanding and broadening the unit of analysis to the organizational level. It implies an integration of several organizational functions, generating new interaction patterns among actors across the organization (Hemon *et al.*, 2020), thereby taking into account the heterogenous and socio-technical nature of digital infrastructures (Hanseth and Lyytinen, 2004). Accordingly, it is of particular importance to understand the interactions that occur between various organizational levels during continuous development. This brings us to the research question underlying our study: *Which patterns of interaction can be identified in the continuous development of digital infrastructures?*

Our empirical approach was a longitudinal case study of a digitalization[1] effort in a Norwegian grid company. The digitalization effort regarded the continuous development of a digital infrastructure, connected to the software OPRA, which implied digitalizing entire workflow and processes involved in the electricians' job executions, through continuously adding services and users to the installed base. To understand the interactions between organizational actors during continuous development, we found the notions of sense-making (Weick, 1995) and sense-giving (Gioia and Chittipeddi, 1991) useful. Following the evolution of OPRA over time enabled us to identify and explicate a pattern of interactions in the continuous development of digital infrastructures. We then used the ideas of sense-making and sense-giving to theorize the interaction patterns and determine how different organizational actors experienced and interpreted the infrastructure evolution to interact constructively.

Our contributions are threefold. First, we contribute to IS research by introducing the idea of continuous development in broader organizational contexts and providing a theoretical definition in that regard. Second, we propose a generic model of continuous development, suggesting two interaction cycles of sense-giving and sense-making between organizational actors enabling continuous growth and increasing benefits from digital solutions. Our model expands the established perspectives on sense-

[1] In this study, we understand digitalization as a process of leveraging digital technology to alter one or several socio-technical structures (Yoo *et al.*, 2010; Osmundsen, Iden and Bygstad, 2018).

giving and sense-making mechanisms. Third, we add to digital infrastructure research by presenting a nuanced perspective on digital infrastructure evolution. For practice, our findings offer valuable insights and new ways to think about digitalization in incumbent firms.

This article is further structured as follows. First, in theorizing continuous development we present relevant literature on digital infrastructure evolution before describing the roots of continuous development as emerged from DevOps and agile development. Then, we combine insights from the literature to outline main characteristics and suggest a definition of continuous development of digital infrastructures. After describing our case and methods for data collection and analysis, we present our findings then, in the discussion, we return to our research question and discuss implications for research and practice. We point to limitations and avenues for further research, before concluding the article.

2. Theorizing the concept of continuous development in broader organizational contexts

To theorize continuous development as an approach to digital infrastructure evolution, we combined and built on elements from theory on digital infrastructure evolution and agile development and DevOps. In this section we present relevant literature on these perspectives before we compare and integrate them in conceptualizing continuous development in the organizational context of digital infrastructure evolution.

2.1 Digital infrastructure evolution

A digital infrastructure[2] is defined as a shared, open, unbounded, and evolving socio-technical system (the installed base), consisting of digital capabilities, users, operations, and design (Hanseth and Lyytinen, 2010), where the 'installed base' can be considered as 'what is already there' (Grisot, Hanseth and Thorseng, 2014). Accordingly, a digital infrastructure is a socio-technical concept, and regards the interconnected network of the social and technical as the key object. Examples of digital infrastructures explored in the IS literature include the Internet (Hanseth and Lyytinen, 2004, 2010), e-health infrastructures (Hanseth and Aanestad, 2003; Hanseth and Lyytinen, 2004; Grisot, Hanseth and Thorseng, 2014; Constantinides and Barrett, 2015; Bygstad and Øvrelid, 2020), electronic prescription infrastructures (Hanseth and Modol, 2021), social media networks (Tempini, 2017), as well as digital infrastructures within telemedicine (Hanseth and Aanestad, 2003), public transport (Koutsikouri *et al.*, 2018), airline (Henfridsson and Bygstad, 2013) waste management (Fürstenau, Baiyere and Kliewer,

[2] Notions such as digital infrastructure, information infrastructure, and IT infrastructure are used interchangeably in the IS literature. In this paper we use the term "digital infrastructure" (Koutsikouri, Lindgren and Henfridsson, 2017).

2019), real-estate (Montealegre, Iyengar and Sweeney, 2019), and industrial manufacturing (Niemimaa and Zimmer, 2020).

Digital infrastructures are not designed but evolve through a combination of actions of many stakeholders (Hanseth and Lyytinen, 2010), building on the notion that the infrastructure is never fully complete—it has several good uses yet to be conceived of (Tilson, Lyytinen and Sørensen, 2010). Accordingly, digital infrastructure evolution can be understood as a gradual process with discrete events over time, by which the installed base grows into more complex forms (Henfridsson and Bygstad, 2013; Montealegre, Iyengar and Sweeney, 2019). The generative, recursive, scalable, and flexible nature of digital infrastructures fosters evolution and growth over time. Through generative mechanisms of innovation, adoption, and scaling, the infrastructures continue to evolve through self-reinforcement (Henfridsson and Bygstad, 2013). Further, as boundaries and standards of digital infrastructures are not set beforehand, their evolution is continuous and unexpected, characterized by gradual growth of users and functionality as users gain experience using the digital infrastructure effectively (Hanseth and Lyytinen, 2004).

The evolution process of digital infrastructures is usually considered as bottom-up (i.e., operationally) driven, taking into account the flexible and generative nature of the digital infrastructure (Hanseth and Aanestad, 2003; Hanseth and Lyytinen, 2004; Grisot, Hanseth and Thorseng, 2014) and its dynamic complexity (Constantinides and Barrett, 2015). In this context, bottom-up means that the digital infrastructure evolves through organic growth in users and functionality, largely outside management control (Niemimaa and Zimmer, 2020). Given that gradual growth of users and functionality are seen as critical drivers for digital infrastructure evolution (Grisot, Hanseth and Thorseng, 2014), cultivation is considered a valuable approach to influence this evolution. Cultivation entails addressing change in an incremental and gradual manner, characterized by three main elements: process-orientation, user mobilization, and learning (Grisot, Hanseth and Thorseng, 2014). In this context, process orientation entails engaging with the technology and the installed base to introduce changes to the digital infrastructure in an incremental and processual manner. User mobilization considers a need for to be motivated and mobilized to adopt new technology for the infrastructure to grow. To accomplish this, bootstrapping is considered effective, which involves targeting the least critical and simplest tasks or practices first, and enrolling the most motivated users first by offering them immediate benefits (Hanseth and Aanestad, 2003). Through bootstrapping, the digital infrastructure can evolve step-by-step, with new steps evolving from the previous steps in a positive, self-reinforcing manner (Hanseth and Lyytinen, 2010; Koutsikouri, Lindgren and Henfridsson, 2017). Finally, learning is considered the driver of any cultivation process, where the “designers judge which parts are functioning well and which parts are not” (Grisot, Hanseth and Thorseng, 2014, p. 201) based on for instance adoption rates.

The inherent generative nature of digital infrastructures, which implies the ability of their "technical and social elements to interact and recombine to produce or expand new solutions" (Bygstad, 2017, p. 181), introduces novel socio-technical relationships and behaviors during their use and growth (Tilson, Lyytinen and Sørensen, 2010). Digital infrastructures are heterogenous, in that they consist of a variety of complex and dynamic components, including technical, organizational, and social components (Hanseth and Lyytinen, 2004), as well user, operations, and design communities (Hanseth and Lyytinen, 2010; Tilson, Lyytinen and Sørensen, 2010). All components and communities involved in the digital infrastructure need to be sustained and organized for the infrastructure to grow and evolve, which requires both technical and social interactions (Fürstenau, Baiyere and Kliewer, 2019), and dynamic interactions between social and technical elements (Constantinides and Barrett, 2015). Accordingly, the concept of digital infrastructure reflects the idea that digital technology is socially embedded and coordinated through socio-technical relations (Tilson, Lyytinen and Sørensen, 2010), and its evolution relies on value-creating interactions between multiple stakeholders (Constantinides, Henfridsson and Parker, 2018) and their understandings of each other's challenges (Bygstad and Øvrelid, 2020).

2.2 From agile to DevOps to continuous development

The concept and practice of agile has its roots in software development. Due to rapid technological development and globalization, organizations have, over time, shifted from stable to emergent organizations—continuously adapting to changes in their environments (Truex, Baskerville and Klein, 1999). This shift led to changes in software development practices (Rodríguez *et al.*, 2017), as traditional approaches—seeking to create stable IS with low maintenance requirements and long life spans—were seen as hindering for emergent organizations in adapting to changing environments (Truex, Baskerville and Klein, 1999; Bello, Sorrentino and Virili, 2002). Instead, organizations should establish more flexible development environments and use IS to support and promote organizational change (Truex, Baskerville and Klein, 1999).

As a response to the traditional software methods, *agile software development* emerged in 2001 (Beck *et al.*, 2001; Rodríguez *et al.*, 2017). At the core of agile development, is *agility*, which can be understood as an ability to exhibit flexibility to accommodate changes rapidly and simply through learning and applying up-to-date knowledge and experience (Alzoubi, Gill and Al-Ani, 2016). Conboy (2009) defined software development agility as the readiness "to rapidly or inherently create change, proactively or reactively embrace change, and learn from change while contributing to perceived customer value (economy, quality, and simplicity), through its collective components and relationships with its environment" (Conboy, 2009, p. 340). Agile development requires effective and efficient communication and collaboration, both among agile team members and with customers (Cao *et al.*, 2009; Tripp, Riemenschneider and Thatcher, 2016), to develop sufficient understanding (Miller, 2001), generate ideas quickly (Highsmith and Cockburn, 2001), and thereby achieve high quality software and customer satisfaction (Tripp, Riemenschneider and Thatcher, 2016). Moreover, frequent interactions with the customers allows for designers to identify challenges early on, adjust priorities, and amend the software according to changing conditions along the way (Highsmith and Cockburn, 2001). This resonates well with the core values of agile development as manifested in the *Manifesto for Agile Software Development* (Beck *et al.*, 2001).

Over time, different variants of agile methods have emerged (Tripp, Riemenschneider and Thatcher, 2016; Berente, 2020), all of which propose different practices; however, they are all predicated on the idea that environments are changing and that it is practically impossible for developers to predict software functionality requirements up-front (Dybå and Dingsøyr, 2008; Berente, 2020). Accordingly, the main goal of agile software development is to improve developers' ability to adapt to changes in the environment and customer needs (Highsmith and Cockburn, 2001; Cao *et al.*, 2009). Over the years, this idea and the agile methodology has evolved to embrace entire organizations—so-called *agile organizations* (Aghina *et al.*, 2017) or *enterprise agile* (Overby, Bharadwaj and Sambamurthy, 2005)—moving beyond software development and the IT department to consider the organizations' ability to sense environmental changes and respond appropriately (Overby, Bharadwaj and Sambamurthy, 2005; Fitzgerald and Stol, 2017), and hence, affecting business aspects such as strategy, structure, processes, people, and technology (Aghina *et al.*, 2017).

One extension of agile that has received increasing attention as an approach to software development and in organizations' innovation processes in general is *DevOps* (Maruping, Venkatesh and Agarwal, 2009; Fitzgerald and Stol, 2017; Hemon *et al.*, 2020). The idea of DevOps emerged as an attempt to increase integration between the organization's development and operations functions (Debois, 2011), which typically are not well aligned in traditional agile methods and thus represents a potential bottleneck (Hemon *et al.*, 2020). In addition to bridging the gap between development and operations, DevOps extends the agile cyclic feedback loop to a continuous feedback loop (Fassbinder, 2019). It focuses on delivering services, not only software (Humble and Molesky, 2011), through incremental development and continuous delivery with small upgrades to services (Ebert *et al.*, 2016).

Compared to agile development—where the agile team comprises people from the developing function—this team was widened with DevOps by adding the operations people, thereby increasing the number of actors who are involved in the development process (Hemon *et al.*, 2020) and whose incentives need to be aligned in developing services and software (Humble and Molesky, 2011). Accordingly, collaboration, interaction, and sharing of knowledge and responsibilities becomes increasingly important in DevOps (Humble and Molesky, 2011; Hemon *et al.*, 2020). In fact, Hemon and colleagues (2020) found in their study that interactions increased in both frequency and efficiency when development teams moved from agile to DevOps, again; highlighting the importance of interactions and collaboration to achieve continuous integration and delivery.

As with agile, DevOps has its roots in startups and Internet-based companies (Iyer and Davenport, 2008; Debois, 2011; Ries, 2011; Ebert *et al.*, 2016). Although these types of organizations are typically characterized by more flexible management structures than incumbent firms, the fundamental ideas behind DevOps thinking is considered to be just as relevant for incumbent firms, since collaboration becomes increasingly important in large organizations where one-to-one communication is difficult to accomplish (Debois, 2011). Moreover, despite its wording (i.e., DevOps = Development and Operations), DevOps does not have to only imply development and operations teams collaborating and working together. Rather, the fundamental ideas behind DevOps thinking should apply to the entire organization (Debois, 2011) in improving digital infrastructures and 'optimizing the whole' (DeGrandis, 2011).

Against this backdrop, the idea of *continuous development*, an umbrella term for DevOps activities such as continuous integration and continuous delivery (Rodríguez *et al.*, 2017; Fassbinder, 2019), is predicted to lead to strategic benefits if implemented throughout organizations (Bussgang and Clemens, 2018). Bussgang and Clemens (2018) argued that continuous development is the 'new agile'; that continuous development has the potential to change organizations, maybe at an even greater extent and in a broader organizational context than agile. Diffusing continuous development as a practice throughout entire organizations can make room for experimentation and innovation, enabling organizations to more quickly respond to changes in customer needs and requirements (Rodríguez *et al.*, 2017; Bussgang and Clemens, 2018).

2.3 Continuous development of digital infrastructures

Where the agile thinking already has gained foothold in broader organizational contexts (Aghina *et al.*, 2017; Fitzgerald and Stol, 2017), following the recommendations of Bussgang and Clemens (2018), we sought to theorize the continuous development line of thought from DevOps in a broader organizational context as an approach to digital infrastructure evolution. With characteristics from both the 'slow' process of digital infrastructure evolution and the 'fast' process of agile development, we situate continuous development in-between these perspectives. Table 1 provides a summary of differences and similarities between the three approaches relevant for this study, followed by a description of each element in the table.

	Digital infrastructure evolution	**Continuous development**	**Agile development**
Focal object	Evolving installed base (Hanseth and Lyytinen, 2010)	Services (Humble and Molesky, 2011; Fitzgerald and Stol, 2017)	Working software (Dingsøyr *et al.*, 2012)
Development process	Incremental and unpredictable, discrete (Hanseth and Lyytinen, 2010) and gradual growth of users and functionality (Grisot, Hanseth and Thorseng, 2014)	Incremental and continuous flow of development, testing, feedback, and learning (Rodríguez *et al.*, 2017)	Incremental (Beck *et al.*, 2001), iterative (Miller, 2001) and exploratory (Dybå and Dingsøyr, 2009)
Value delivery	Evolutionary through combined actions (Hanseth and Lyytinen, 2010) and value-creating interactions (Constantinides, Henfridsson and Parker, 2018)	Continuous through learning-driven user involvement and frequent testing and deployment. Interactions between actors on different organizational levels (Hemon *et al.*, 2020)	Cyclic through regular short intervals (Dingsøyr *et al.*, 2012) of innovation, testing, and modification (Berente, 2020)
Governance	Bottom-up	Bottom-up and top-down	Bottom-up

Table 1. Continuous development in relation to digital infrastructure evolution and agile development

Focal object. In contrast to agile development, where the focal object is working software (Dingsøyr *et al.*, 2012) developed to serve dedicated tasks, the focal object of digital infrastructure evolution is an evolving and heterogenous installed base (Hanseth and Lyytinen, 2004). Continuous development, then, regards delivering or adding services to the installed base on a continuous basis (Koutsikouri *et al.*, 2018), making the services offered to the community the focal object. As such, continuous development extends the idea of agile in also taking the operations and business case into consideration.

Development process. Whereas both digital infrastructure evolution and agile development can be considered incremental development processes, unlike digital infrastructure evolution, agile development is not a discrete process. Digital infrastructure evolution is unpredictable, in that it does not relate to any specific plan or goals (Hanseth and Lyytinen, 2004). Rather, its development depends on the gradual growth and adoption rate of users, which is reinforced by adding functionality that meet the users' needs of simplicity and usefulness (Koutsikouri, Lindgren and Henfridsson, 2017). While agile development is also not driven by predefined requirements, the development process is more exploratory (Dybå and Dingsøyr, 2009) and emphasizes working solutions (Berente, 2020) to serve emerging problems. Continuous development combines elements from both agile and traditional digital infrastructure evolution, in that the installed base grows in users and services on a continuous basis, through a continuous flow of development, testing, feedback, and learning (Rodríguez *et al.*, 2017).

Value delivery. In traditional digital infrastructure theory, value delivery can be considered evolutionary, enabled by the combined actions (Hanseth and Lyytinen, 2010) and interactions (Constantinides, Henfridsson and Parker, 2018) of several stakeholders involved in the sociotechnical structure. With agile, value delivery occurs at a more regular and cyclic basis through pre-defined, short intervals of testing and amendments to the software (Dingsøyr *et al.*, 2012; Berente, 2020), and as such emphasizes intense collaboration and communication to create value (Miller, 2001; Berente, 2020). Continuous development extends the agile perspective by moving from cyclic to continuous value delivery (Rodríguez *et al.*, 2017; Fassbinder, 2019), and involves updating software and adding services to the digital infrastructure continuously, and involving users and their data throughout the development process, thereby enabling quick releases (Bussgang and Clemens, 2018) to test new ideas with users to drive user satisfaction (Bosch, 2012). Accordingly, user input (Rodríguez *et al.*, 2017) and interactions between actors on different organizational levels (Olsson, Alahyari and Bosch, 2012; Hemon *et al.*, 2020) are considered main drivers for value delivery in continuous development.

Governance. Agile development and digital infrastructure evolution are mainly considered as bottom-up approaches, driven by the demands and needs of users, largely outside management control (Highsmith and Cockburn, 2001; Niemimaa and Zimmer, 2020). Continuous development is also reliant on the demands and responses of users in adopting new services of the digital infrastructure, however; it also requires management to be on board. It requires a balance between stability and flexibility, and control and autonomy, and hence, is perhaps best governed through a combination of top-down influences and bottom-up adaptations (Niemimaa and Zimmer, 2020).

To summarize, DI evolution regards expanding the installed base through gradual growth of users and functionality through cultivation and bootstrapping. Agile development can be characterized by the emphasis on people (putting individuals and interactions over processes and tools; Beck *et al*., 2001), in developing working software through collaboration and responsive actions to respond to changes. Continuous development extends the idea of DevOps to broader organizational contexts, with a focus on adding services to the digital infrastructure and growing in users based on continuous feedback from users and learning among actors across organizational levels. Based on this understanding, we suggest defining continuous development as *the incremental growth of services and users in a digital infrastructure through short cycles of development and learning.* In the following sections, we present our research approach and findings in exploring the forces of continuous development in a specific organizational context.

3. Case and methods

Data to answer the research questions was derived from a longitudinal case study at a Norwegian grid company, "GridCo". A case study involves studying a case within a real-life, contemporary context over time through detailed, in-depth data collection from multiple sources (Creswell, 2012). The research was longitudinal, in that we followed the case organization over time, from autumn 2018 to spring 2020. Rich access to the case organization enabled us to develop a deep understanding of the organization and its approaches to digitalization. In the following, we first describe our case, and then we outline how data was collected and analyzed.

3.1 Case description

GridCo is a Norwegian grid company, responsible for building, operating, and maintaining the grid network for a specific geographic area in Norway. Grid companies ensure that electricity is generated and distributed to their customers (e.g., private households and industrial actors). Since it is not economically viable to build grid networks next to each other, each grid company in Norway holds a natural monopolistic position based on its geographical area of operation. However, development in the sector is challenging the traditional role and monopoly position of the grid companies. Enabled by emerging digital technology and trends such as electrification, self-generation, and local energy solutions (e.g., micro-grids), the entire system for generating and distributing energy is changing. At the same time, new competitors, ranging from large enterprises and non-industry entrants to small start-up companies, are entering the energy sector. Additionally, in Norway, regulators are introducing regulations and guidelines that change the dynamics in the sector, leading the players toward increased cooperation, changed roles, new business models, and new ways of approaching end users. GridCo realized that they needed digital transformation to leverage the digital development, prepare the organization for the future, and remain relevant and competitive. In this article, we deeply explored one digitalization effort that contributed to the digital transformation at GridCo: namely, the development of the digital infrastructure connected to the software OPRA.

GridCo has approximately 400 employees, over half of whom directly support the company's obligation to provide electricity to customers. This involves both personnel working *inside* in planning and administrating jobs to be executed, and electricians working *outside*, physically executing the work.

Figure 1. Electricians at work

The fieldwork conducted by the electricians is "rather rough, mechanical work" (Interviewee 13), which involves physical, manual execution. As one respondent commented:

> You can talk about digitalization and robotization and the like, but our grid system is how it is. Some of it was built over 100 years ago and still exists. So, we need to be there physically to execute the work … Someone still has to do the physical job—we can't escape that (Interviewee 7).

The electricians' work is driven by customer inquiries. An inquiry regarding a fault on the grid, or a need for electricity in a new location, triggers a job to be executed. One challenge at GridCo was a lack of structure and standardization in receiving and handling customer inquiries, which extended to the entire process of planning, executing, and documenting jobs. Different individuals had their ‘own ways’ of working, and the various work methods resulted in limited recording and poor documentation. Additionally, the information systems supporting the processes were not well integrated, which obliged employees to move back and forth between systems and applications, duplicating work and information; as a result, many avoided the information systems entirely, which limited the management’s insight and control.

Today, the situation is entirely different. From 2014-2019, a digital infrastructure linked to the software OPRA[3] was continuously developed at GridCo. The evolution of the digital infrastructure involved digitalizing entire workflows and processes preceding and following the physical execution of the electricians’ job. OPRA is not merely an IT solution, but a collection of roles, interactions, activities, and ways of working that contribute to the functioning of entire work processes at GridCo. Accordingly, the OPRA software represents the core and installed base of the digital infrastructure by which was self-made and gradually grew over time through continuously adding services and roles. The digital infrastructure connected to the OPRA software is recursive, scalable, and flexible, allowing for the technical and social elements of the infrastructure to interact and be recombined to continuously expand the reach of the installed base. Hereinafter, we refer to the digital infrastructure connected to the OPRA software as the ‘OPRA infrastructure’, or just ‘OPRA’.

Figure 2 illustrates the overall process flow that the OPRA infrastructure encompasses, from customer inquiries to planning, execution, and documentation. The OPRA software consists of four parts: OPRA *Portal* is the ‘entry gate’ for inquiries, where work orders are created for further processing; OPRA *Process* assigns work orders to the correct workflows and activities; OPRA *Resource* is a resource allocation application, through which the resource allocators assign resources to work orders; and OPRA *Mobile* is the electricians’ tool for receiving work orders, managing their workday, and documenting the jobs. The figure also illustrates the roles involved in the processes and different parts of the OPRA infrastructure, as well as the information systems integrated with the OPRA software.

[3] OPRA = Tasks (in Norwegian; "Oppgaver") Processes, Resources, Administration

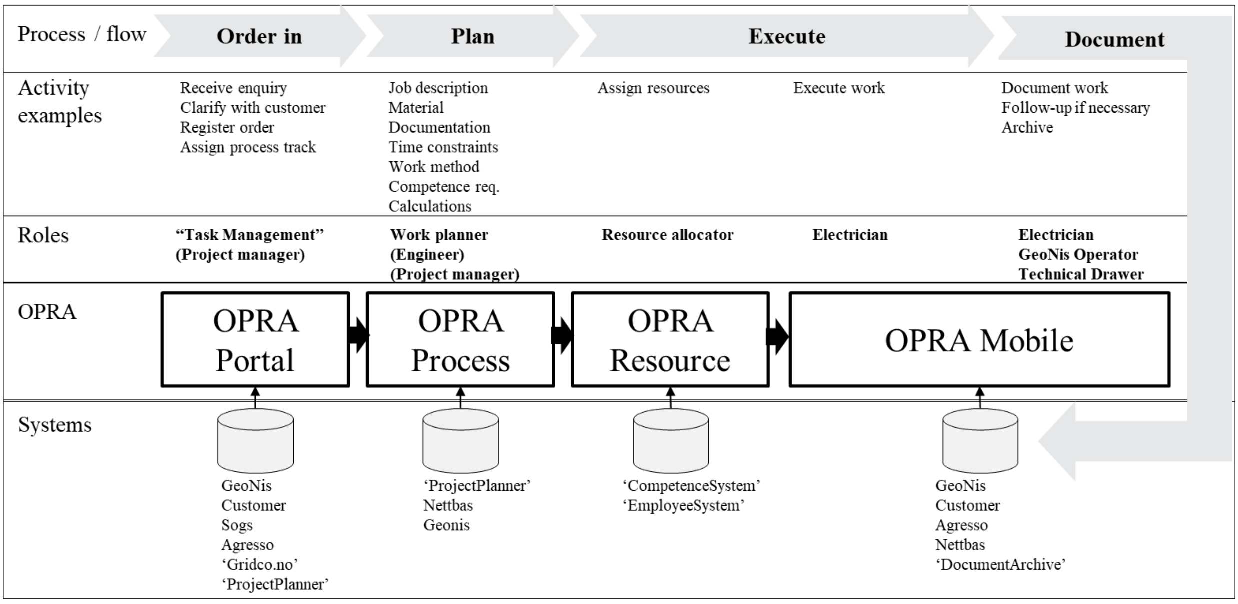

Figure 2. OPRA infrastructure and connected processes, activities, roles, and systems

The OPRA infrastructure encompasses the entire value chain of GridCo, from receipt of a customer inquiry to work planning, execution, and documentation. Managers and employees today refer to OPRA as a 'revolution'; however, as our study illustrates, the journey to reach that point was not straight forward.

3.2 Data collection

We relied on three sources of data in our research: interviews, observations, and archival documents, where the interviews served as our main data source. We conducted semi-structured interviews with 45 respondents in different positions and departments in the company. Each interview lasted between 30 minutes and 2 hours. The interviews were tape-recorded, with the respondents' consent, and transcribed verbatim. In total, the interviews generated more than 500 written pages of transcripts. Respondents included four top management representatives, 14 middle management representatives, and 27 operational employees. Nineteen of the respondents had previous experience as electricians at GridCo. An overview of the interviewees is presented in Table 2.

	Number of respondents	*Formerly electricians at GridCo*
Top Management	**4**	**-**
Middle Management	**14**	**5**
Operational employees	**27**	**14**
Project Manager	*7*	*4*
Work Planner	*5*	*5*
Engineer	*5*	*2*
Technician/Craftsman	*4*	*2*
Advisor/Senior Advisor	*3*	*1*
Digital Advisor	*3*	-
Total	**45**	**19**

Table 2. Interviewees

Observations were also a source of data, enabling us to view the organization from an insider perspective (Jorgensen, 1989). Since one researcher spent one to three days a week in the case organization as an *outside observer* (Walsham, 1995) for more than eighteen months, we were able to conduct rich observations by overseeing discussions, working side-by-side employees, participating in lunchtime talks, and overseeing several meetings, including department meetings, project meetings, management meetings, and staff meetings. Observations were documented in over 100 pages of field notes, constituting a valuable data source and foundation for data analysis.

Our study also included extensive archival data, accessed through the organization's document archive system and other company information systems. This included strategy documents, project plans, presentations, budgets, and a significant number of postings and news items on the internal communication platform. This data served mainly for establishing a foundation and understanding of the case organization and OPRA project.

3.3 Data analysis

To analyze the data, and to progress from first level constructs (i.e., quotes and understandings held by the case study participants) to second-level constructs (i.e., our understandings as observing researchers) (Lee and Baskerville, 2003), we were inspired by the "ladder of analytical abstraction" (Carney, 1990; Miles, Huberman and Saldaña, 2013) and worked in three phases (see Table 3).

Phase	Activities	Outcomes
1. Familiarizing ourselves with the data: capturing the "story" of OPRA	• Reading and re-reading data • Understanding the case organization • Understanding the OPRA infrastructure • Generating codes • Noting initial ideas	• Case description (section 3.1) • Description of the OPRA infrastructure (Figure 2) • Codes related to continuous development • Ideas for subsequent steps
2. Identifying themes: understanding the OPRA evolution	• Coding data • Identifying three themes: Continuous development process, Interactions, and Organizational actors • Collating codes and data extracts to themes • Analyzing the OPRA evolution	• Coded data extracts • Thematic map (Figure 3) • Understanding the OPRA evolution as continuous development (section 4.1, Figure 4) • Identifying interactions during continuous development of OPRA (section 4.2) • Realizing the crucial role of middle managers (section 4.3)
3. Understanding interactions: theorizing interaction patterns	• Analyzing interactions during OPRA development - how organizational actors interpret the continuous development ○ Applying ideas of sense-giving and sense-making	• Understanding and theorizing pattern of interactions, with two interlinked cycles (Figure 6)

Table 3. Phases of data analysis

Phase 1. Familiarizing ourselves with the data: capturing the "story" of OPRA

In the first phase, interview transcripts, observational field notes, and archival documents were read and re-read, to develop an understanding of the case as foundation for further data analysis. Familiarizing ourselves with the data and using an open coding approach enabled us to write up the case description (section 3.1) and develop a clear picture of OPRA as a digital infrastructure—how it worked, which processes and activities it supported, which roles it involved, and how it interacted with existing information systems. Accordingly, we were able to model the OPRA infrastructure, as illustrated in Figure 2, which was verified by an OPRA expert to ensure that our understanding was accurate. During this phase, we generated codes for further analyzing the data to understand the OPRA evolution and noted down ideas for further data analysis.

Phase 2. Identifying themes: understanding the OPRA evolution

In the second phase, we were concerned with understanding how the OPRA infrastructure evolved through continuous development. We approached the data again, this time focusing on coding the data according to the definition and main characteristics of continuous development. We studied the codes and accompanying data extracts in detail, reviewed and validated codes, and then collated codes and accompanying data extracts to three themes in a thematic map (see Figure 3): Continuous development process, Interactions, and Organizational actors. Some examples of data extracts and codes linked to each theme are provided in the appendix.

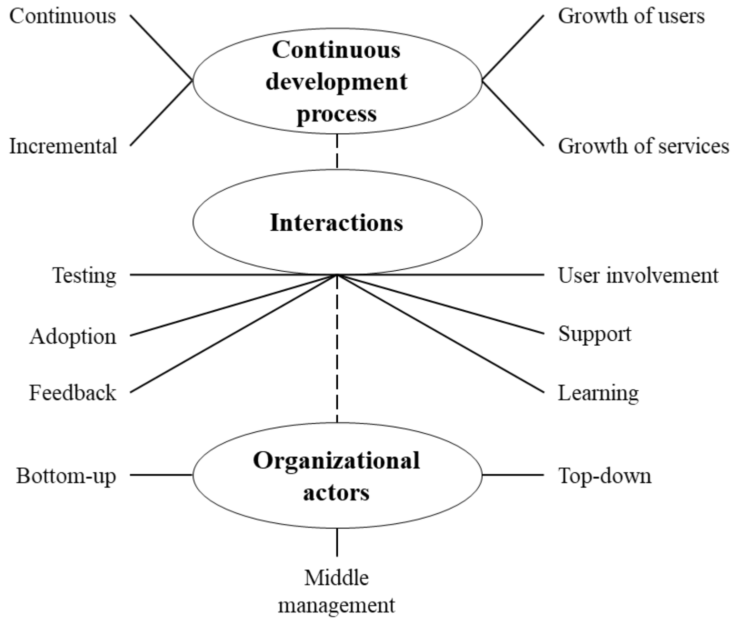

Figure 3. Thematic map data analysis

Structuring and analyzing the data through coding activities and the thematic map enabled us to understand the continuous development of the OPRA infrastructure, including the activities and key events driving the OPRA evolution and how different organizational actors were involved in the continuous development (section 4.1). This understanding led to the construction of Figure 4 presenting a chronology of key events and actors involved in the OPRA evolution. In this phase, we also identified interactions occurring between different organizational actors during the continuous development of OPRA (section 4.2) and realized the crucial role of the middle management (section 4.3).

Phase 3. Understanding interactions: theorizing interaction patterns

In the third phase, driven by our research question, we were interested in understanding the interactions identified in more detail. Continuous development of a digital infrastructure is dependent on a continuous flow of communication and learning between different organizational levels, which for incumbent firms—where the distance between top management and operational employees traditionally is rather large—involves new and complex ways of interacting and working together. Hence, it was not enough to merely understand which organizational actors interacted and how they did so; we also needed to understand how different organizational actors reflected upon the continuous development during these interactions. In other words, we needed to determine how different organizational actors experienced and interpreted the continuous development of OPRA to interact constructively.

To do so, we found valuable the notions of sense-making and sense-giving, originating from the work of Weick (1995). *Sense-making* can be understood as a process by which organizational actors engage in retrospective and prospective thinking to interpret reality; in other words, a process whereby individuals 'make sense' of a reality (Weick, 1995; Jensen, Kjærgaard and Svejvig, 2009). *Sense-giving* (Gioia and Chittipeddi, 1991) is a process whereby organizational actors (e.g., managers) attempt to influence the meaning construction of other organizational actors (e.g., employees), toward their preferred reality, through for instance communication and actions (Gioia and Chittipeddi, 1991); in other words, sense-giving implies a process of trying to influence others' sense-making (Maitlis and Christianson, 2014).

Accordingly, in this third phase, we carefully analyzed the interactions and applied the perspectives of sense-making and sense-giving to understand the interactions occurring between different organizational actors during continuous development of a digital infrastructure such as OPRA. This analysis enabled us to theorize a generic pattern of interactions, in two interlinked cycles (top-down and bottom-up), illustrating organizational dynamics of continuous development (Figure 6).

4. Findings

Our data analysis revealed three key findings, which are elaborated in the following sections:

- The OPRA infrastructure evolved through continuous development, involving actors on three organizational levels: top management, middle management, and operational employees.
- The continuous development was fueled by interactions between the middle management and top management on the one hand, and between the middle management and the operational level on the other.
- Middle management played a crucial role in the continuous development

4.1 Continuous development of the OPRA infrastructure

Figure 4 illustrates a chronology of events in the evolution of the OPRA infrastructure. We found that actors at three organizational levels were involved in the continuous development: top management, middle management, and the operational level. Top management refers to managers at the senior levels in the organization. Middle management refers to middle managers and representatives from the IT department, including the OPRA team—people who strove for OPRA to become a reality and who continuously developed the OPRA infrastructure. By the operational level, we refer to employees working in processes directly affected by the OPRA infrastructure, including electricians, engineers, work planners, job allocators, and project managers: people who make up almost two-thirds of the entire work force at GridCo. The largest group consists of electricians; the employees who use the OPRA software on the most regular basis.

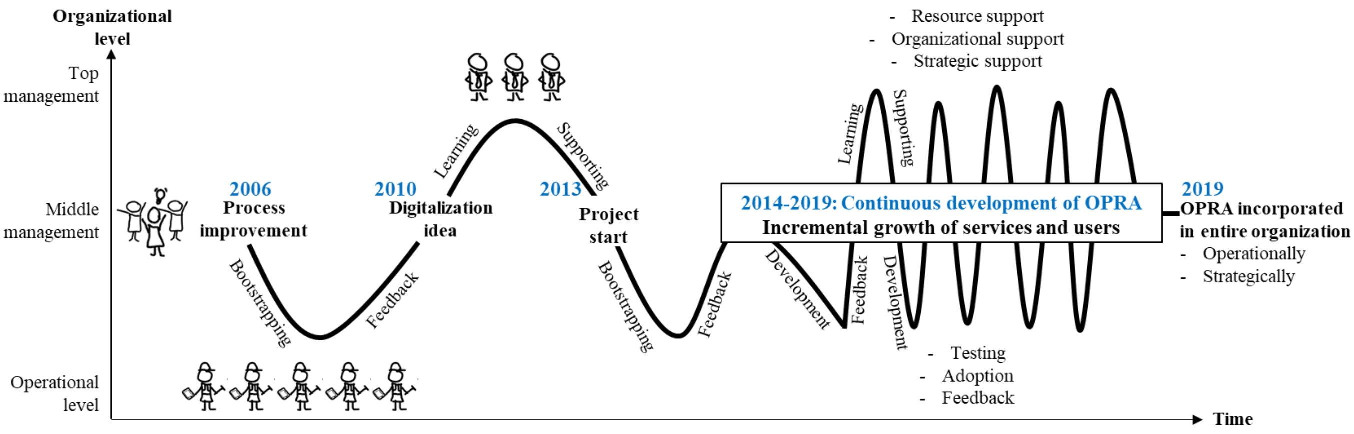

Figure 4. Chronology of the evolution of OPRA

In **2006**, a middle manager in charge of a department of 40 electricians decided to take action to standardize and optimize the work routines in the department. Her aim was to ensure that the electricians worked as efficiently as possible. To do this, better control of, and insight into, the core business was necessary: "I had a plan to improve [our services] and, if I were to do that, I needed to know my production! I had to know what the electricians were capable of doing within a workday" (Interviewee 45). Gradually, she worked on standardizing tasks and processes in the department and took measures to enhance the electricians' application of existing information systems. To achieve this, a bootstrapping approach was applied, starting with the simplest tasks and engaging the most motivated electricians first.

The efforts made in the department to standardize and optimize the ways of working were successful, however; the information systems supporting the workflow were still not working optimally and were not well integrated. Furthermore, the efforts only concerned *one* department and a small fraction of employees, affecting only a small number of processes at GridCo. Building on the experiences from her own department, the middle manager saw the potential to extend the scale and scope to include the entire organization. In **2010**, she proposed an idea to the top management: to develop a software and infrastructure that would collate and digitalize all tasks and processes at GridCo relating to planning, resource allocation, and documentation of work orders to be executed. The aim was to ensure effective job instructions and necessary documentation following work orders, enable interaction between systems and people, and provide process support through mobile devices (iPads).

However, the idea received only limited support from the top management and, frankly, the operational employees were not pleased with the idea either: "The solution was wanted by neither the management nor the electricians. 'Why do we need it? We should just continue doing our job'" (Interviewee 2). According to the interviewees, top management did not recognize the pressing need for change and, hence, did not see the value of such an infrastructure: "As a company we should have control of our production. And I don't really think the management understood that—why we needed that [laughing]" (Interviewee 45). "The challenge was getting the management to understand what this was all about, because they were completely absent", said Interviewee 19. The lack of sense of urgency, some respondents suggested could be linked to the traditionally safe and stable position of GridCo, leading to digitalization being underdeveloped in the organization: “Digitalization and talking about digitalization in this company was still very new and unfamiliar. Very unfamiliar!” (Interviewee 45).

Together with a handful of ambassadors, the middle manager worked on reframing the idea and its potential to convince the top management. In **2013**, the top management eventually gave their go-ahead for the OPRA project to start. A project team (‘OPRA team’ hereafter), consisting of middle managers closely connected with the IT department at GridCo, was given the mandate to ‘kick-start’ the development of OPRA. When the core of the software and infrastructure was in place, a bootstrapping approach was applied for the initial implementation of OPRA. Processes in which “tasks were simple and of high volume” (Interviewee 45) were targeted first, which implied adding services to serve the tasks of a small group of employees. These employees were offered extensive training and were closely monitored by the OPRA team. They were not pleased about having to work with the OPRA software initially, because they “liked it better the way things were before, on paper” (Interviewee 7). However, as these users came to understand OPRA, they also recognized its value and the resistance from the employees decreased.

Based on feedback from the users, the OPRA team, with help from the IT department, made necessary adjustments to OPRA to accommodate the needs, and reduce any frustrations, of the users at the operational level. From **2014** onwards, OPRA continued to evolve through what can be characterized as continuous development: Additional services were added to OPRA incrementally, and more and more employees adopted the software. The continuous development of the OPRA infrastructure evolved as a self-reinforcing process with short development and learning cycles, fueled by feedback from the operational level, and top management support.

Together with the IT department, the OPRA team continuously developed OPRA, releasing new versions of the OPRA software and adding services to the infrastructure on a continuous basis based on the feedback they received from the users. Initially, the reactions of the users were mainly negative, characterized by frustration and resistance; however, through training and adjusting the solution based on users’ feedback, the resistance faded. Furthermore, by continuously improving OPRA to meet users’ needs and adding services, the number of employees adopting OPRA increased, which in turn led to feedback from a broader user base and increased learning to support continuing development. To illustrate this with an example, one major change with OPRA was the transition from laptops to iPads.

Figure 5. Electricians with iPads

In January 2017, iPads with OPRA Mobile were rolled out to all electricians, but the transition proved challenging. The mobile application had several errors: “Everything did not necessarily work exactly as it was supposed to in the beginning. So that was kind of a brutal start” (Interviewee 1). This generated frustration among the electricians:

> It was kind of like, when they first made up their mind, an iPad was handed out to all of us: “Now you have to use OPRA on the iPad!” But it didn’t work! And that led to many detours around OPRA. Because our work had to proceed anyway, right? And I think that led to detours for a long time [after the problems were solved]; longer than necessary, because people didn’t trust the solution and didn’t like using it (Interviewee 18).

Many electricians had limited experience with iPads in general, especially some of the senior workers: “Some of them managed, but others couldn’t even turn it on. There are different generations, right. When you’re 60 years old and are handed an iPad, it’s kind of like: ‘What is this thing?’” (Interviewee 25). Although iPads generated resistance and frustration among electricians, these attitudes faded over time as they came to understand the functionality and value of the iPad and OPRA Mobile: “Many were frustrated in the beginning. Yes, people weren’t very pleased with it, but that has changed. They have seen the benefits of it. I think it’s like a maturation process” (Interviewee 24). Important initiatives from the OPRA team that contributed to easing the resistance included taking the needs and requests of the electricians into account to continuously improve the solution, adding the services required by the employees, and offering appropriate training. As one former electrician pointed out: “I was not happy with the iPad or OPRA. But things are different today. Now I see the value of it. Things have turned! [laughing] And I’ve realized that it’s not a problem to learn new technology, so I’m not reluctant to digitalization anymore” (Interviewee 9).

As the OPRA infrastructure continued to grow in services and user base, top management also eventually realized its potential value and gradually came to express their support for OPRA through reinforcing actions, allowing the continuous development of OPRA to flourish. Examples of such supporting actions included dedicating IT resources to OPRA, re-invigorating a process-based mindset in the organization, establishing an organizational unit to manage the continuing development and implementation of OPRA, and placing an increasing focus on OPRA and digitalization in the business strategy.

When interviewing both employees and managers at GridCo in **2019**, it was clear that resistance toward OPRA had faded out. Top management now referred to OPRA as ‘revolutionary’, in that it had increased standardization and efficiency across the entire value chain, and they now had data-based insight into the business. OPRA was seen as the backbone for the wider digital transformation at GridCo and had gained strategic anchoring in the organization. The employees at the operational level now also saw the value of OPRA. Even the most resistant employees had turned:

> To be honest, I was very skeptical as to whether it was going to work. I was a bit opposed to it, thinking they were moving a bit too fast forward. But, I have to say, the team working with the OPRA solution, they have done a fantastic job. It works. So I’ll be the first to admit that I was wrong there! [laughing] (Interviewee 21).

4.2 Interactions between organizational levels reinforcing continuous development

We found that the continuous development of the OPRA infrastructure was fueled by interactions between different organizational actors: the operational level and middle management on the one hand, and the middle management and top management on the other.

The OPRA team added services to the infrastructure and released new versions of the OPRA software continuously. Operational employees tested, adopted, and evaluated the new services considering whether previous problems had been solved, whether new problems had occurred, and whether the new services added value to their daily work. Based on their experience and evaluation, they had some sort of reaction. If their experience was bad, they reacted with resistance, but if their experience was good, they were more likely to continue to embrace OPRA, convince their peers to use the OPRA applications more extensively, and search for new ways to further improve the infrastructure. They expressed their opinions of the new services, mainly through feedback to the OPRA team at the middle management level. One employee commented:

> We have seen that giving feedback works. They adjust [OPRA] according to our needs, and that makes me believe that we get a solution that we have much more ownership of. You get a solution that does what you need it to do; not only a solution that is forced on you (Interviewee 3).

These interactions between the middle management and operational level occurred continuously. New versions of the OPRA software were released on a continuous basis, and services were added or changed to the infrastructure based on the learning and feedback from the operational level users, who again adopted and tested, and again; provided feedback to the middle management. At the same time, middle management interacted with the top management to ensure that they had enough support and resources to continue the development of the OPRA infrastructure. As explained earlier, the top management were not convinced of the value of OPRA initially, but despite their earlier lack of confidence, they never held up the continuing development of OPRA:

> There was some resistance from the top levels as well, so there was no guarantee that OPRA would succeed. However, the management have given us leeway, so we had permission. It was never stopped. And one ever said: “No, now we can’t afford developing anything else, this is enough”. So, management never stopped it, but they maybe didn’t cheer very much either, at least for a while (Interviewee 45).

Nevertheless, middle management continuously strove to make the benefits of OPRA apparent to the top management, to win sufficient support for its continuing development. As more users adopted OPRA, the learning increased and the organizational benefits of OPRA became clearer. Implementing OPRA eventually reduced the time operational level employees spent on administration, solved inconsistencies in work orders, and reduced the number of trips electricians had to make back and forth between the office and the field. According to an internal audit report, time spent on documentation and administration of a typical job was reduced from 22 days in 2014 to 3 days in 2018. Moreover, interviewees reported benefits such as increased transparency, standardization, and efficiency. Demonstrating these benefits of OPRA to the top management was an important task for middle management. Over time, the top management learned the valuable and positive effects of OPRA, and gradually showed their support and provided resources to reinforce the continuing development of OPRA.

4.3 The role of the middle management in continuous development

As indicated by the nature of the interactions as described in the former section; middle managers played a crucial part in the continuous development of the OPRA infrastructure. Their role was essential for ensuring that users’ needs were met and acting as a bridge between the top level and the operational level, and consequently, they took on roles as change agents.

By considering and learning from the demands and needs of the operational employees, middle management ensured that OPRA simplified the electricians’ work, rather than merely representing ‘just another system’. Employees expressed their needs and demands to the OPRA team on a regular basis: “We can report [to the OPRA team] at any time. Kind of like improvement suggestions. There is always something to improve. So OPRA is improved and updated all the time” (Interviewee 24). A middle manager also commented on how they worked rapidly to meet the feedback from the employees: “The employees are quick to notify if something is not functioning with OPRA. And the OPRA team are quick to fix it” (Interviewee 11). As a result, middle management ensured that the socio-technical properties of the OPRA infrastructure were developed according to the work context of the electricians, by adapting and adding services to OPRA, promoting its use, and establishing appropriate communication norms.

Middle management acted as a bridge between the top management and operational employees, translating needs and demands from and to both parties, and reducing gaps between the different perspectives. Interactions with organizational actors on each level helped developing a shared understanding of OPRA and its place in the organization. In addition to considering feedback from the operational level, the middle management also provided feedback to the top management. On several occasions, the middle managers approached the top management with suggestions regarding operational, organizational, and strategic matters, based on the continuous development of OPRA and with the operational employees' needs and perspectives in mind. One middle manager commented:

> We get to come up with some suggestions, like: "You have to include this as a part of the organizational development". And I have had one-to-one conversations with [the CEO], where I have been quite clear on "this is what we have to focus on now to move forward" (Interviewee 45).

Consequently, we observed that these middle managers assumed roles as change agents (Balogun, 2003) in advocating OPRA's continuing development and managing the organizational changes following OPRA. One middle manager explained how she took a stance to bring OPRA into force: "I took a position where I said that I wanted all work orders to go through OPRA. I took the lead that this was to be done. I attended a top management group meeting and expressed this" (Interviewee 10). The middle management also acted as change agents in placing digitalization on the agendas of both the top management and the operational level employees, cultivating new ways of working that focused on documentation and standardization:

> There are two things that are important in my view: one is the understanding the company has gained of the importance of digitalization, and the second is that we are starting to have an incorporated work methodology, in that you need a work order for jobs, that you need to follow a process, and that documentation is important. The methodology is essential in my mind. We must not stop documenting and we must not stop thinking "digitalization" (Interviewee 45).

Although the middle management had to manage a great deal of resistance and "got a lot of bashing" (Interviewee 28) during the evolution of OPRA, their contribution and important role is today acknowledged at GridCo. An internal audit report highlighted:

> There has been a determination to persevere that has been crucial for the realization of OPRA despite the strong resistance. The driving force, and most important success factor, seems to have been the OPRA team's firm conviction that it was essential to measure and make the work processes more efficient (personal communication, 5 November, 2018).

5. Discussion

In this section, we return to our research question: which patterns of interaction can be identified in the continuous development of digital infrastructures?

Considering our findings, we identified clear interaction patterns between actors at different organizational levels. From 2014 to 2019, OPRA continued to evolve through a continuous development process, where the OPRA infrastructure was expanded by adding services and growing in users. This all happened through the interplay of and interactions between middle management, operational employees, and top managers. In line with the literature, the continuous development of OPRA was characterized by short cycles development and learning. The most characteristic feature of the case was that the development process was fueled by experiences at the operational level, triggering learning at higher organizational levels.

In reflecting on the interaction patterns identified in the continuous development of OPRA, we found the ideas of sense-making (Weick, 1995) and sense-giving (Gioia and Chittipeddi, 1991) useful to understand the details of the interactions occurring during continuous development. These perspectives focus on how and why different actors construct interpretations and try to affect other actors' interpretations, while seeking to create order (Weick, 1995; Lewis, Mathiassen and Rai, 2011). Digital infrastructure evolution, despite occurring in an incremental manner, may interrupt organizational actors' current ways of working (Jensen, Kjærgaard and Svejvig, 2009). Some actors may engage in sense-making to understand the continuous development and the attendant changes, which informs their future actions, whereas other actors may engage in sense-giving to foster the continuous development. By drawing on these ideas, we sought to understand how key actors in the organization interpreted, understood, and reacted to the continuous development of the digital infrastructure. This is particularly relevant in the context of technology-related change as is the case with OPRA, because new technology can have several alternative interpretations (Weick, 2000) and actors at different organizational levels may interpret new technology and changes differently, based on their underlying assumptions, expectations, and knowledge about the technology (Orlikowski and Gash, 1993). Accordingly, understanding how different organizational actors make sense of the digital infrastructure is essential for understanding its evolution.

In context of technology implementation, the traditional perspective has been that employees (i.e., users of the new technology) typically engage in sense-making processes to develop assumptions, expectations, and knowledge of the technology, which in turn shape how they interact with the technology (Orlikowski and Gash, 1993). This sense-making process is triggered by the changes inferred by the technology implementation, such as interruptions to individuals' current projects or ways of working (Jensen, Kjærgaard and Svejvig, 2009). At the same time, managers are typically portrayed as the organizational actors engaging in the related processes of sense-giving (Gioia and Chittipeddi, 1991;

Maitlis and Lawrence, 2007; Maitlis and Christianson, 2014). What surprised us in the case of the continuous development of the digital infrastructure OPRA, were the sense-making and sense-giving mechanisms: in contrast to previous assumptions; in our case it was the operational level that was giving sense, and the top management who were making sense.

From our findings and conceptualization of continuous development of digital infrastructures, inspired by the ideas of sense-making and sense-giving, we propose a generic pattern of interactions with two interlinked cycles, fueling and reinforcing the continuous development of digital infrastructures (Figure 6). The pattern of interactions combines a top-down approach of sense-making and a bottom-up approach of sense-giving, with the first cycle at the top management level and the second at the operational level.

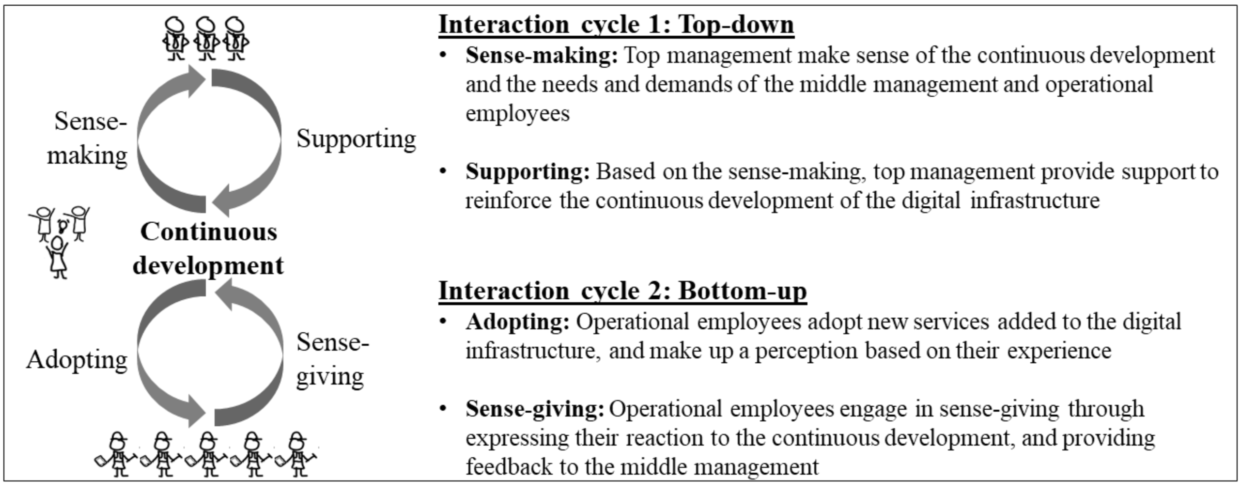

Figure 6. Interaction patterns

In the first interaction cycle, we identified two interaction mechanisms unfolding: *sense-making* and *supporting*. The top management made sense of the continuous development and gradually increased their learning and understanding of the middle management's arguments for the continued development of the digital infrastructure, as well as the needs and requirements of the operational employees. In other words, in this context, top management engaged in sense-making to understand the continuous development of the digital infrastructure and how this development affected the organization. This sense-making informed top management's future actions in providing resources for the middle management to improve and extend the digital infrastructure, and, thus, supporting the continued development.

In the second interaction cycle, the interaction mechanisms we identified were *adopting* and *sense-giving.* The operational employees adopted the added or amended digital infrastructure services and created a perception of the digital infrastructure based on their experiences. They then engaged in sense-giving, attempting to influence the sense-making at higher levels and steer the continuous development of the digital infrastructure in a direction that suited their needs. In other words, sense-giving, in this context, concerned the process of operational employees influencing the middle- and top managements' perceptions of the continuous development through feedback and reactions.

5.1 Implications for research and practice

In this article we have theorized and explored the concept of continuous development in the broader organizational context of digital infrastructure evolution. The idea of continuous development and our model of interaction patterns (Figure 6) extends the research on digital infrastructures, which has argued that digital infrastructures evolve organically and unpredictably, by bootstrapping and cultivation, basically outside managerial control (Hanseth and Lyytinen, 2010; Grisot, Hanseth and Thorseng, 2014). Our analysis shows that continuous development, is dependent on structured interactions between employees and management, and cycles of sense-giving and sense-making. This insight highlights that continuous development of digital infrastructures requires a more nuanced picture, indicating that the evolution is neither a top-down nor a bottom-up approach, but rather a combination of the two. In this perspective, the digital infrastructure evolves through continuous interactions between different organizational levels. Placed in the middle of the model are the middle managers, indicating that middle management play a central role in continuous development. In our case, the role of the middle management particularly revolved around presenting the needs of the users, bridging gaps, and acting as change agents during the continuous development.

Our model further provides a nuanced perspective of the established view of sense-making in organizations, which largely assumes that top managers conduct the sense-giving and that sense-making, on the receiving end, is a bottom-up process. Our model indicates that employees at the operational level can engage in sense-giving, which in turn involves top management actors engaging in sense-making to understand the situation and take appropriate action. This can be explained by the user-intensive nature of continuous development (Bosch, 2012); thus, we find that the high degree of user involvement in the continuous development approach, based on short learning and development cycles at the operational level, results in a shift in the directions of who is giving and making sense of digital infrastructure evolution.

From a more practical perspective, we contribute with insights on digitalization in incumbent firms by exploring the forces of continuous development in the context of digital infrastructures. Digitalization is challenging for incumbent firms (Yoo, Henfridsson and Lyytinen, 2010; Sebastian *et al.*, 2017; Svahn, Mathiassen and Lindgren, 2017; Warner and Wäger, 2019). As illustrated in our case, incumbent firms have to combine digital and physical elements when digitalizing (Yoo, Henfridsson and Lyytinen, 2010). For companies like GridCo, that operate complex physical assets and depend on a field force to run their business, digitalization is particularly challenging. Consequently, and as our case illustrates, digitalization revolves around combining digital elements with existing physical constructions, manual work routines, and social interactions. Furthermore, in incumbent firms with a large field force of employees, the distance between the top management and operational level becomes increasingly apparent when digitalizing (Kohnke, 2017). Top management does not necessarily have direct experience with the effects of digitalization on the operational employees; for example, having to incorporate digital tools in the daily work while hanging from a pole or digging a ditch. Consequently, it can be challenging for managers to incorporate the direct needs of the operational employees when digitalizing. How can incumbent firms succeed in digitalization under such conditions? We argue that continuous development is a fruitful approach for incumbent firms embracing digitalization, by supporting short learning and development cycles at the operational level.

The continuous development approach accommodates some of the most common barriers to digitalization in incumbent firms. We believe that the emphasis on deep and systematic user involvement and learning in continuous development lays the ground for incumbent firms to succeed in digitalization. Continuous development allows for heavy user involvement in digitalization, through short learning and development cycles. Accordingly, incumbent firms can take experiences and challenges encountered during the digitalization process into consideration and make appropriate adjustments. The ability to turn around quickly is essential in emergent organizations (Truex, Baskerville and Klein, 1999), and even more so in today's digital era. In our case, feedback from the operational environment served as input for learning and further improvement and digitalization. A continuous development approach ensures that the digitalization satisfies the needs and demands of the employees; hence, there is no need for extensive change management (Helmke, 2019). Our case illustrated that, although there was initial resistance to digitalization, once an appropriate cycle of continuous learning and development was in place, the resistance faded away.

5.2 Limitations

Our theorization of continuous development is based on our understanding of digital infrastructures and derived from the DevOps approaches to software development. Our understandings may differ from that of other researchers, and our approach should be applied in other contexts to explore its tenability.

Our findings and model of interaction patterns during continuous development are based on a single case study in one incumbent firm in Norway, and we have reflected on whether our findings could be particularly relatable to the Scandinavian context. The Scandinavian approach to digitalization and organizational change emphasizes engaging employees in deep participation and drawing on the knowledge of employees at different organizational levels (Bygstad, Aanby and Iden, 2017), which might have contributed to the success of the continuous development approach at GridCo. Further, as our case illustrates, we suspect that continuous development presupposes a well-functioning installed base in the organization as a foundation, and that the organization posits competence to continuously develop this installed base. Future research should investigate the facilitating conditions of continuous development in more detail, as well as under which conditions continuous development is most appropriate.

That being said, although the case setting in this study may be unique, we still would argue that our findings and model can be expanded and generalized to other contexts (Walsham, 1995; Yin, 2014). We have approached our data collection and analysis thoroughly and consistently, providing a rich description of the case context and data, and how these data were analyzed to generate insights.

6. Concluding Remarks

In this article, following the recommendations of Bussgang and Clemens (2018) and recent trends within software development, we sought to expand and theorize the concept of continuous development to broader organizational contexts. Although the idea of continuous development is not new (Dingsøyr and Lassenius, 2016), it represents a new way to think about digital infrastructure evolution and digitalization. Moreover, the ability for firms to engage in continuous development in broader organizational contexts is increasing with maturing digital technology (Dingsøyr and Lassenius, 2016; Berente, 2020) supporting the ability of incumbent firms to rapidly deploy new services to their digital infrastructures and elicit customer feedback from testing (Lindgren and Münch, 2016). We explored the continuous development of the digital infrastructure connected to the OPRA software at the Norwegian grid company GridCo. Our research question was, which patterns of interaction can be identified in the continuous development of digital infrastructures?

Through our study and answering the research question, we offer three contributions. First, we offer a theoretical definition of continuous development in a broader organizational context. Second, we propose a model of continuous development, which shows how two interaction cycles of sense-giving and sense-making enables continuous growth and increasing benefits from digital solutions. The model expands the established perspectives on sense-making and sense-giving mechanisms. Third, we add to digital infrastructure research by presenting a nuanced perspective on digital infrastructure evolution. From a practical perspective, we offer valuable insights and new ways to think about digitalization in incumbent firms.

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Appendix: Codes and data extract examples

Data extract example	Code	Theme
"*OPRA is continuously developed, so new changes and updates are continuously added based on what is appropriate to include*" (7, middle) "*There have been some 'childhood diseases' with OPRA, but they have been very good at continuously solving them as they emerge*" (21, operational)	Continuous	Continuous development process
"*[The OPRA team] have cleared away most of the problems with OPRA along the way*" (23, operational) "*We have implemented OPRA gradually. Adding one element at a time*" (45, middle)	Incremental	
"*Our work processes are linked to OPRA. Not all of them are. There has been a development from around 5% to around 90% of our core processes linked to OPRA*" (35, middle) "*Eventually OPRA made rapid progress, we got more work orders in and more users adopted it*" (11, middle)	Growth of services	
"*OPRA is improving as increasing number of employees adopt it*" (9, operational) "*We started with one group of users in OPRA in the beginning. And then we have added more and more users*" (45, middle)	Growth of users	
"*You have to make use of OPRA and gain some experiences, and then make changes based on the needs of the users*" (1, top) "*The employees realize that OPRA can integrate all the things they need, and that they can take part by suggesting improvements*" (19, operational)	User-involvement	Interactions
"*If you don't test things, or make sure things work as they should, then it is more likely that negative attitudes towards the solution arise***"** (32, operational) "*I have been part of the development of OPRA since the beginning, kind of like a 'test subject'. I have tried out all the versions that didn't work for anything*" (8, operational)	Testing	
"*Management established resources to drive the continued development of OPRA*" (45, middle) "*I think management became more interested. And started to 'talk up' OPRA themselves, in that they started to realize that this perhaps was kind of smart"* (45, middle)	Support	
"*First the users have to understand, and then we can make the next steps in OPRA*" (45, middle) "*OPRA has been a maturation process*" (24, operational)	Learning	
"*[OPRA] is under continuous development. We are not at the finish line yet, but it is constantly improved, and new users are continuously adopting OPRA*" (1, top) "*The more users adopt OPRA, the more feedback we get on things that need to change in OPRA*" (11, middle)	Adoption	

"*The input from the electricians in the field is crucial*" (6, operational) "*We can report [to the OPRA team] at any time. Kind of like improvement suggestions. There is always something to improve. So OPRA is improved and updated all the time*" (24, Operational)	Feedback	
"*We need someone in the middle who understand what the users want, what IT need, and what management require. Because the users want everything really, and IT can accommodate almost everything, but how long will it take and how much does it cost*?" (10, middle) "*It has been crucial to have people on board [the OPRA team] who know the work processes and who actually and genuinely want change*" (45, middle)	Middle management	Organizational actors
"*Sometimes we just need to get told 'this is something you have to do' [laughing]*" (9, operational). "*Top management need to provide a direction*" (41, middle)	Top-down	
"*We have had the opportunity to provide input and suggestions to the top management the whole time. But of course, not everything we suggest do they want to do, or are they able to do, but that's just how it has to be*" (45, middle) "*We try to develop OPRA based on the wishes of the users. We can never sow it together in a way that pleases everyone. But we make improvements that we believe are beneficial for everyone*" (11, middle)	Bottom-up	

Article 3

Title: Familiarity with artifact totality: Exploring the relation and perception of digital twin affordances through a Heideggerian perspective

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Under review at journal: Information Systems Journal

Abstract: The concept of affordances has become central in information systems literature. However, existing perspectives fall short in providing details on the relational aspect of affordances, which can influence actors' perception of them. To increase granularity and specificity in this regard, researchers have suggested that it be supplemented with other concepts or theories. In this article, we argue that the Heideggerian concepts of "familiarity" and "referential totality" are well suited for increasing our understanding of the relational aspects of affordances in information systems research. To explore these concepts, we conducted a case study of a digital twin project in a Norwegian grid company. We found that users' familiarity with the artifact totality enabled them to perceive digital twin affordances, and that without this familiarity, affordances remained latent for the users. Our study makes a threefold contribution to information systems research: first, by specifying the relational aspect of affordances; second, by providing valuable insights into how digital twins are understood and applied in practice; and third, by explaining the mechanisms that need to be in place for users to develop familiarity with the artifact totality.

Keywords: affordance, familiarity, referential totality, digital twin, digital transformation

1. Introduction

The theory of affordances has proven valuable in information systems (IS) research when investigating and explaining socio-technical phenomena (Chatterjee et al., 2021; Leidner et al., 2018). Affordances are broadly viewed as possibilities of actions in the relation between an IT artifact and a goal-directed actor (Leidner et al., 2018; Markus & Silver, 2008; Strong et al., 2014). This means that affordances are not viewed as properties of the artifact nor the actor, but rather as possible actions that arise in the actor–artifact relation (Chemero, 2003; Majchrzak & Markus, 2013). However, what this relation implies and what needs to be in place for the relation to lead to affordance perception is not specified in detail. Researchers have suggested that factors such as context (e.g., Bernardi et al., 2019; Lehrer et al., 2018; Seidel et al., 2013), culture (e.g., Leonardi, 2011a; Rico & Xia, 2018; Thapa & Sein, 2018), and norms (e.g., Costall, 2012; Essén & Värlander, 2019; Faik et al., 2020) may influence affordance perception in the relation between actor and artifact. However, these perspectives focus on actors working in isolation and interacting with artifacts to achieve their goal, while in reality, we would argue, the actors are already embedded in the context and perceive in everyday practice. While IS researchers have provided valuable insight into factors and processes by which affordance actualization is driven or influenced (e.g., Burton-Jones & Volkoff, 2017; Leidner et al., 2018; Li et al., 2020; Strong et al., 2014; Thapa & Sein, 2018), the relational aspect of affordance perception remains unclear (Lanamäki et al., 2016; Seidel et al., 2013). To better understand how actors perceive affordances, we need a more holistic understanding of the relational aspect of affordances.

Following Lanamäki et al. (2015), who suggested that the affordance concept be supplemented with new concepts to increase granularity and specificity, we set out to explore whether perspectives from the *Heideggerian philosophy* might help increase our understanding of the relational aspect of affordances and its perception. We found the perspectives of Martin Heidegger to be suitable for this endeavor because of his fundamental focus on ontological inseparability (Riemer & Johnston, 2017), moving away from the dualistic view of actors and artifacts as separate entities. We specifically found the concepts of *familiarity* and *referential totality* from Heidegger's *Being and Time* (1962) as relevant. According to Heidegger, humans are thrown into a "world" (e.g., a workplace) with a series of possibilities available to them in encountering and interacting with entities (Critchley, 2020). *Familiarity*, then, can be described as a background understanding of this world in which humans need to deal with the world and its entities in a non-deliberate way, which is embedded in know-how, related to specific contexts, and accumulated over time through practice or experience (Heidegger, 1962; Riemer & Johnston, 2017). Riemer and Johnston (2017) noted that, according to Heidegger, it is only on the basis of familiarity that an actor can encounter any artifact, and, in that the way, an actor's understanding of an artifact is always an "interpretation on the basis of this precognitive, background understanding [(i.e., familiarity)]" (p. 1063). Regarding *referential totality,* Heidegger stated that humans always encounter equipment (i.e., artifacts of practical means) in reference to themselves and other equipment, and that equipment always serves to enact a purpose and an identity (Heidegger, 1962; Turner, 2005). In other words, the referential totality of equipment involves the everyday, practical use of the equipment (i.e., the task one could perform with it), as well as the purposes of the tasks and the identity the human could assume in doing so.

These two concepts of Heidegger can potentially increase our understanding of the actor–artifact relation, which is needed to better understand affordance perception. Hence, the objective of this work is to explore *how the Heideggerian concepts of familiarity and referential totality help specify and increase our understanding of the relational aspects of affordance perception.* To do so, we conducted a case study of a digitalization project in an incumbent firm in Norway—a project concerning the development of a digital twin at GridCo, one of the largest and oldest grid companies in Norway which provides electricity to more than 240,000 customers through over 27,000 kilometers of aerial power lines and underground power cables. A digital twin is a virtual representation of a physical object (Grieves, 2014), allowing the user to digitally mirror and manage the object through its life cycle (Dietz & Pernul, 2020), and it can potentially be of great value for organizations in transforming their business (Seidel & Berente, 2020). However, the question of how increasingly complex digital artifacts, such as digital twins, are understood in the workplace still needs to be answered. Loaded with hourly and real-time data on grid network structure, configuration, and electricity consumption, the digital twin replicates the physical grid infrastructure in a digital space and redefines relationships (Nambisan et al., 2019) between organizational actors and the physical counterpart of the twin. Being susceptible to almost any kind of data from its physical counterpart (Dietz & Pernul, 2020; Grieves & Vickers, 2017; Madni et al., 2019), the digital twin offers users a wide array of potential action possibilities (i.e., affordances)—which are likely to evolve even further as data and features are added. Against this backdrop, the GridCo digital twin serves as a valuable case to explore the relational aspects and how the potential users at GridCo came to perceive digital twin affordances.

Following the digital twin project over time, we were able to collect rich data, which we analyzed to understand how and why the users perceived digital twin affordances, through a Heideggerian lens. We found that the users perceived digital twin affordances because they developed a familiarity with the tasks they could perform with the digital twin, the purposes of doing so, and the identity they would assume in doing so. In other words, the users developed a familiarity with the digital twin totality. Based on our findings and the theoretical foundations, we developed a theoretical model in which we specified the relational aspect of affordance perception through familiarity with the artifact totality. The contribution of this article is therefore threefold. First, we are adding to the IS field by specifying and expanding the relational aspect of affordance theory with a focus on perception of affordances. Second, as research on digital twins is still nascent, we contribute by exploring how such complex digital artifacts are understood and applied by users in specific contexts. Third, we suggest that the relation leading to affordance perception is not as simple as the actor–artifact relation; rather, affordance perception is possible if the actor is familiar with the totality of the artifact, and we also explain mechanisms which could lead to this familiarity.

In this article, we proceed by first presenting the status quo on the affordance discourse in IS research and highlighting the specific research gap regarding the relational aspects of affordance perception. We then present Heideggerian thinking and the concepts of familiarity and referential totality. This is followed by the research design and context of the empirical study. Following that, we present the results from our empirical study. Based on our findings and the theoretical backgrounds, we develop an enriched theoretical model based on Heideggerian concepts of familiarity and referential totality and discuss the implications of our model. We end with a conclusion, discussion of limitations, and an outlook for further research.

2. Theoretical Background

In this section, we present the theoretical perspectives underlying our research. First, we cover affordance theory and present existing views on the relational aspect of affordance perception in IS research. Thereafter, we introduce the Heideggerian concepts of familiarity and referential totality as an alternate view to understand relation.

2.1 Perceiving Affordances in Actor–Artifact Relations

The term affordances was introduced by ecological psychologist James J. Gibson (1904–1979) in his study of animals' perceptions of their surroundings. Gibson believed that animals (including humans) directly perceive what an artifact in their environment will enable them to do—that the artifact, in relation to the animal, holds affordances, that is, what is offered, provided, or furnished to someone or something by an object (Gibson, 1986; Strong et al., 2014). As such, affordance theory states that actors perceive the world as affordances, or action possibilities, that exist naturally in the environment and arise in the relation between artifact and actor. Affordances are broadly viewed within the IS field as possibilities of actions that arise in the relation between an IT artifact and a goal-directed actor (Leidner et al., 2018; Markus & Silver, 2008; Strong et al., 2014). The affordance perspective enables IS researchers to study how technology and social actors interact (Strong et al., 2014) and takes a socio-technical view, allowing researchers to be specific about the technology, while, at the same time, incorporating social and contextual aspects (Volkoff & Strong, 2018). Within the IS field, affordance theory has typically been applied to theorize socio-technical phenomena (Leonardi, 2013; Markus & Silver, 2008) and to understand IT-associated organizational change (e.g., Strong et al., 2014; Tim et al., 2020), IT implementation and adoption (e.g., Du et al., 2019; Porter & van den Hooff, 2020; Volkoff & Strong, 2018), effects of IT artifact applications (e.g., Klecun et al., 2016; Leidner et al., 2018; Verstegen et al., 2019), and IT design (e.g., Bardram & Houben, 2018; Benbunan-Fich, 2019; Klecun et al., 2016; Maier & Fadel, 2009).

In this context, affordance perception regards the process where the actor interprets and recognizes the action possibilities offered to them in relation to an artifact. Taking the view that affordances need to be perceived in order to be acted upon (Bernhard et al., 2013), perception is generally understood as occurring in the actor–artifact relation and relying on the features or properties of the artifact and the capabilities and goals of the actor (Bernhard et al., 2013; Pozzi et al., 2014). The artifact holds some features and properties, providing the actor with information about the action possibilities offered to them—enabling the actor to interpret and, hence, perceive the affordances (Bernhard et al., 2013).

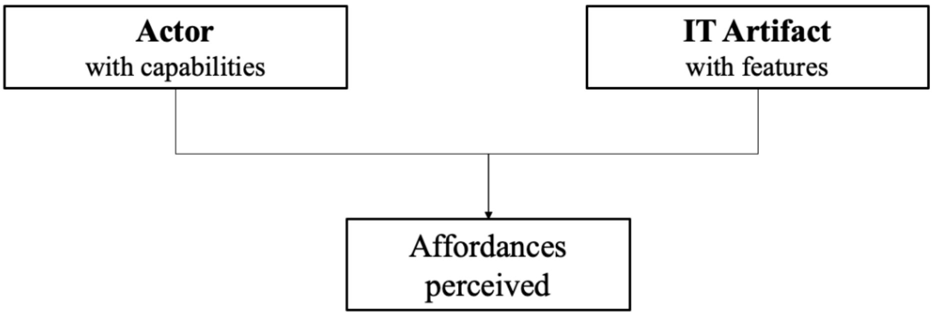

FIGURE 1 Traditional perspective on affordance perception (inspired by Pozzi et al., 2014 and Lanamäki et al., 2016)

In the IS literature, perception has also been portrayed as being subject to influence from factors such as context, culture, and norms. For instance, some researchers posit that affordance perception is influenced by *sociocultural and organizational contexts* (Bernardi et al., 2019; Lanamäki et al., 2016; Seidel et al., 2013). Leonardi (2011b) explained how "technologies have material properties, but those material properties afford different possibilities for action based on the contexts in which they are used" (p. 153). For example, Strong and colleagues (2014) found that electronic healthcare records (EHRs) provided a capable physician (e.g., with the skills for creating electronic notes) with the affordance of capturing and archiving digital data about patients (among other affordances). The authors suggested that the physician's perception of this affordance was influenced by an organizational context characterized by a culture that supported patient data as a clinic resource. However, as Thapa and Sein (2018) emphasized, if the context were different, other affordances might have been revealed. For instance, Lehrer and colleagues (2018) suggested that contextual factors such as "strategies, customers, competitive environment, values, and regulations" (p. 430) might influence which affordances are perceived by the actor. Others have argued that affordances are designed into the artifact and that affordance perception is based on conformity, meaning that the designers based on anticipated interpretation embed the affordances in the artifact through intuitive design (Lanamäki et al., 2016). As such, the design of an artifact should ensure that affordances are easily perceptible by imagined users (Leonardi, 2011b). However, the organizational *culture* (Rico & Xia, 2018) or individual cultural background of the user (Leonardi, 2011a) has the potential to influence affordance perception, which can lead to nonconformity gaps between affordances designed in the artifact and the perceived use of the artifact. It has been further suggested that affordance perception is influenced by social and cultural *norms* (Fayard & Weeks, 2007); that is, the historical and social narratives of the context may affect which affordances arise from the actor–artifact relation (Essén & Värlander, 2019; Thapa & Sein, 2018). For instance, Faik and colleagues (2020) suggested that which affordances are perceived by an actor would depend on the institutional logics and societal norms within the societal order or context in which the actor and artifact reside. Hence, affordance perception should perhaps be considered within wider social frameworks (Costall, 2012).

2.2 A Heideggerian Perspective on Actor–Artifact Relations

Martin Heidegger (1889–1976) was a German philosopher and seminal thinker, most known for his contributions to phenomenology (i.e., the study of experience). In his most prominent work, *Being and Time* (1962), first published in 1927, Heidegger presented his ontological focus in explaining the meaning of *being* (*Dasein*), as well as the so-called Heideggerian equipment analysis (Harman, 2010; Riemer & Johnston, 2017). A well-known expression of Heidegger is *being in the world*, which can be translated to the most basic condition of humans: to already be in the world prior to any experience (Riemer & Johnston, 2017). A world, for Heidegger, is made of "practices, equipment, and skills shared by a specific community" (Van de Walle et al., 2003, p. 2), and can be multiple, local worlds—such as a family, a workplace, an industry, or society in general (Riemer & Johnston, 2017). As such, every human being is part of some world (a broader, encompassing context; Dreyfus, 1998), which contemplates a particular culture or established ways of life (Riemer & Johnston, 2017). Human existence in this world is, according to Heidegger, defined by time—human beings exist with a past, move through a presence, and have available to them a series of possibilities, which they can seize hold of, or not (Critchley, 2020). Whereas *existence* (engagement in practices; Riemer & Johnston, 2014) denotes the way of being of humans, Heidegger distinguished between two types of being of other entities in the world: *presence-at-hand* (the way of being of objects) and *readiness-to-hand* (the way of being of what Heidegger refers to as *equipment*) (Riemer & Johnston, 2014, 2017), where the latter concept was the most important to Heidegger. Equipment are entities of practical means, encountered in fluent use (Riemer & Johnston, 2017), and according to Heidegger, the most frequent way humans encounter and deal with equipment is by taking them for granted as items in everyday use, rather than having them in consciousness (Harman, 2010).

Heidegger's philosophical thinking is complex and rather difficult to grasp (Critchley, 2020; Horrigan-Kelly et al., 2016); however; his contributions are highly recognized in research, in general, and within the IS field (Lanamäki et al., 2015; Riemer & Johnston, 2017). In this paper, our aim is not to go into detail into Heidegger's thinking. Rather, following our research interests, we look into the two concepts of *familiarity* and *referential totality* from Heidegger's *Being and Time* (1962), and explore how these concepts may help increase our understanding of the relational aspects of affordance perception.

Heidegger's terminology is relevant for understanding IT artifacts and their use (Riemer & Johnston, 2014) and has enabled us to explore an actor's engagement in a social and material world (Riemer & Johnston, 2017). The concepts of familiarity and referential totality Heidegger are used to explain and articulate the relation of humans with their environment and have allowed us to study the actor–artifact relation from a more nuanced perspective.

2.2.1 Familiarity

According to Heidegger, actors possess familiarity with themselves, others, entities, and their interrelatedness in a world, which shapes their self-understanding (Teal, 2009) and enables them to cope with situations and equipment (Turner, 2005). Familiarity is a background understanding that actors need to deal with the world and its entities in an absorbed and non-deliberate way (Riemer & Johnston, 2017), embedded in know-how (Riemer & Johnston, 2014), related to specific contexts, and accumulated through practice or experience. Actors rely on familiarity, for instance, when brushing their teeth or mastering an instrument, where knowledge to conduct the activity is enacted and not actively thought (Teal, 2009). As such, actors require some individual learning to acquire sufficient familiarity with the artifact to encounter it in a practical and unreflective way (Riemer & Johnston, 2014). Van de Walle and colleagues (2003) identified three ideas underlying an actor's familiarity with the world. First, the actor is *involved* in the world, which provides a feeling of being-at-home. Second, to relate to the world, the actor has an *understanding* of themself and the world, which, according to Heidegger, is not merely related to knowledge, but skill and capacity to do something, manifested through taking part in activities in the world. Third, familiarity implies a *unity of self and world*, meaning that the actor in being involved in and understanding the world understands themself as integrated in the world. Familiarity itself is not observable; however, outcomes of familiarity are observable by which an actor conducts themself in performing activities with, for instance, easiness, confidence, and success (Van de Walle et al., 2003). Translated to our study, we understand familiarity as an actor's background understanding, involvement, and engagement in a world, making the actor ready to cope with artifacts within this world. Using GridCo as an example, familiarity could, for instance, regard an actor at GridCo's understanding of, involvement in, and prior engagement in practices in the grid company and grid sector in general, which would prepare the actor to cope with a "new" artifact within this same "world."

2.2.2 Totality

Heidegger referred to the world as a totality of referential totalities and explained how equipment always belongs to a totality of equipment. Equipment is essentially something *in-order-to* something (Heidegger, 1962), what Heidegger referred to as *readiness-to-hand*. An actor does not encounter equipment as objects with properties, but as practical or handy means: in-order-to's (Riemer & Johnston, 2017). Accordingly, equipment is always viewed in terms of its belonging to other equipment (Critchley, 2020). For instance, a hammer is encountered as in-order-to hammer something; thus, it is not meaningful to consider a hammer without reference to other equipment such as nails and wood. The totality of equipment depends on three interrelated elements. First is what Heidegger referred to as the *for-which* (i.e., for which task the equipment is used) (Riemer & Johnston, 2014, 2017). In other words, the character and tasks of equipment in reference to other equipment (e.g., the shape and construction of the hammer in relation to nails and wood, implies hammering) (Turner, 2005). Second is the *toward-which* (i.e., toward which purpose) (Riemer & Johnston, 2014, 2017), meaning the set of purposes or use practices (Riemer & Johnston, 2014) to which performing these tasks are put (e.g., building a wall or a house) (Turner, 2005). Third is the *for-the-sake-of-which* (i.e., the bearing equipment has on an actor) (Riemer & Johnston, 2014; 2017). For Heidegger, equipment always serves to enact an identity, in that an actor assumes a particular identity in performing the purposed tasks with the equipment (e.g., the identity of a carpenter) (Turner, 2005). Translated to our study, we understand totality as the artifact's referential whole; the tasks the actor could perform with the artifact (in relation to other artifacts), the purpose(s) of the actor performing these tasks, and the identity the actor could assume in doing so. Using digital twins as an example (e.g., a digital twin of a manufacturing asset), the referential totality the digital twin would involve the tasks one could perform with the digital twin (e.g., schedule maintenance on the asset) in relation to the physical asset and other artifacts as well as the purpose of performing the tasks (e.g., to prevent damage to the asset), and the identity the actor could assume in doing so (e.g., proactive member, contributor to prolonged life cycle of the asset).

TABLE 1 Summary of Heideggerian concepts applied in this study

	Core elements	**Relational description**
Familiarity	• The actor is *involved* in the world • The actor has *understanding* of themself and the world • There is a *unity of self and world*	An actor's background understanding, involvement, and engagement in a world, making the actor ready to cope with artifacts within this world.
Totality	• *For-which* (i.e., for which task the equipment is used) • *Toward-which* (i.e., toward which purpose) • *For-the-sake-of-which* (i.e., the bearing equipment has on an actor)	The artifact's referential whole; the tasks the actor could perform with the artifact (in relation to other artifacts), the purpose(s) of the actor performing these tasks, and the identity the actor could assume in doing so.

3. Research Design of the Empirical Study

To explore how the concepts of familiarity and totality could help specify the relational aspects of affordance perception, we conducted a case study (Creswell, 2012) of a digital twin project in a large Norwegian grid company, referred to as GridCo.

3.1 Case Description

GridCo is one of the largest grid companies in Norway, responsible for building, operating, and maintaining the regional and local grid network in a specific geographic area to distribute electricity to customers. The company was founded in 1920, has approximately 500 employees, and has a long tradition of fulfilling its obligation to provide electricity to its 240,000 customers. The purpose of the DigitalGrid project is to develop a digital twin of the grid network in Norway. DigitalCo is the project owner and responsible for developing the digital twin—building on its experience with digital twin development in other industries. GridCo represents the main user partner in the project. It is involved in the development and design of the digital twin, and the digital twin is based on GridCo's grid network data and processes. In addition to GridCo, the project partners consist of two other grid companies, two research institutes, and one software company. The project started in February 2018 and has a projected duration of approximately three years. Within the project duration, DigitalCo aims to have developed a minimum viable product (MVP): a digital twin prototype that illustrates sufficient value for GridCo and other grid companies for them to want to acquire a full solution from DigitalCo. This paper addresses the digital twin prototype, hereinafter referred to as the *digital twin* or *twin*.

A digital twin is a virtual representation of a physical asset or object, which allows a company to digitally mirror and manage this asset through its life cycle (Dietz & Pernul, 2020). In general terms, a digital twin consists of three main components: (1) a physical object in real space, which can be tangible or intangible; (2) a virtual object in virtual space (e.g., in the cloud); and (3) connections between the virtual and the physical space, consisting of data and information tying the physical and virtual together (Grieves, 2014). All kinds of data (e.g., performance data, health data, maintenance data; Madni et al., 2019) can be extracted from the physical object to the virtual object to replicate the reality, providing the user with information on the physical object's condition and state (Dietz & Pernul, 2020).

In our case, the digital twin is a digital twin of the grid network in Norway—the twin is a georeferenced digital representation of how the grid network is laid out in reality, based on GridCo's grid network data. The twin is available in a map-based application, where the users are presented with a map of the grid network area. The map shows all components in the grid network in their exact location (e.g., house branch lines, distribution cabinets, feeder cables, grid substations, cable lines, substation departures, and substations) and accompanying information on each component (e.g., voltage level, type of cable, length of cable, electrical properties, alarms, and warnings). Predefined rules based on grid sector standards underlie the graphical presentation of the grid network components. If a component has a yellow color, it is reaching its loading capacity (80% of nominal current), whereas a red color indicates the component is overloaded (over 100% of nominal current). In Figure 2, we have included some screenshots from the first version of the digital twin.

FIGURE 2 Digital twin screenshots

The idea is that, in the future, the digital twin will be able to incorporate and combine data from additional internal sources and external sources. In addition to being designed based on standardized rules and an open information model, the digital twin consists of four feature categories:

- Insight: Showing an actual, modeled, and predicted state of the grid. Includes features such as visualization, topology processing, forecasting, and time machine.
- Planner: Planning grid operations in the short term and grid investments in the longer term, where the users get decision support from scenario-based simulations. Includes features such as capacity calculator, investment calculator, grid templates, and scenario analyzer.
- Optimizer: Providing optimal asset utilization, both technical and economic. The features help the users in balancing investments with operational measures, such as voltage regulation, flexibility, and topology changes. Includes features such as optimal grid configuration, optimal power flow, optimal scheduling, and micro grid operation.
- Health: Providing consolidated risk exposure of operation and investments. This involves risks related to condition, health, safety and environment (HSE), outages, overinvestments, and quality of supply. Includes features such as risk forecasting (condition monitoring), dashboards, and portability.

3.2 Data Collection

We relied on three sources of data over the course of three phases of the DigitalGrid project: interviews, observations, and archival data; however, the interviews served as our main data source. Table 2 illustrates the different data sources.

TABLE 2 Data sources

		Phase 1 (2018)			Phase 2 (2019)			Phase 3 (2020)		
Interviews	*Role*	*No. of interviews*	*Respondent ID*	*Duration*	*No. of interviews*	*Respondent ID*	*Duration*	*No. of interviews*	*Respondent ID*	*Duration*
	DigitalGrid project member (GridCo)	4	1;2;3;6	278 min	1	8	47 min	7	1;3;6;8;19; 22	501 min
	Manager (GridCo)	1	5	55 min	2	10;12	114 min			
	Employee (GridCo)	2	4;7	112 min	8	9;11;13;14; 15;16;17; 18	378 min			
	DigitalGrid developer (DigitalCo)							2	20;21	126 min
	In total	**7**		**445 min/ 7.4 h**	**11**		**539 min/ 9.0 h**	**9**		**627 min/ 10.5 h**
Observation	• Working side-by-side project members and other organizational members 1–3 days per week • Daily conversations with project members • Participation in weekly and monthly meetings, seminars, and workshops • Three demonstrations of the digital twin versions 1, 2, and 3 • Participation in 4 sprint demonstrations • >100 pages of written field notes									
Archival data	• Formal project documentation • Internal project documentation (GridCo) • Strategic documents (GridCo) • Other relevant documents									

We conducted 27 interviews with 22 respondents during the three phases. Some respondents were interviewed more than once. Each interview lasted from 40 to 90 min. With the respondents' consent, the interviews were recorded and transcribed verbatim. In the first two phases (2018 and 2019), 18 interviews were conducted with respondents working in a variety of positions and departments in GridCo, some of whom were more directly involved in the DigitalGrid project than others. In addition, interviews non-related to the DigitalGrid project were conducted with 28 respondents from GridCo during this period, which served as a foundation for gaining a rich understanding of GridCo and the Norwegian grid sector. In the third phase (2020), we focused our interviews more directly on those involved in the DigitalGrid project, supplementing with interviews from respondents from the developing company, DigitalCo. In total, nine semi-structured interviews were conducted in the third phase: seven interviews with GridCo respondents and two interviews with DigitalCo respondents. The interview guide from the third phase is available in Appendix A.

Observation was another important data source, enabling us to view the organization and project from an insider perspective (Jorgensen, 1989). One author spent 1–3 days a week with GridCo for almost two years, participating in meetings, seminars, and workshops. Working side-by-side with DigitalGrid project members and attending demonstrations of the different versions of the digital twin provided rich insight into the project and the twin. Observations were documented in over 100 pages of field notes, constituting a valuable data source and foundation for data analysis. Our study also included extensive archival data. We accessed both formal and internal project documentation, including presentations, budgets, and plans, from the project members and their collaboration platforms. In addition, we were able to access strategic documents and intracompany information regarding the DigitalGrid project through the grid company's document archival system and internal communication platform.

3.3 Data Analysis

We applied thematic analysis to analyze our data, a useful and flexible method for identifying, analyzing, and reporting patterns across qualitative data (Braun & Clarke, 2006). *Themes* refer to abstract constructs identified by researchers before, during, and after analysis to capture important aspects of the data according to the aim of the research. We chose a theoretical approach to our thematic analysis; our analysis was driven by our theoretical interests and research objectives. We followed six steps in analyzing the data, inspired by the phases of thematic analysis presented by Braun and Clarke (2006) (Table 3).

TABLE 3 Data analysis steps (inspired by Braun & Clarke, 2006)

Step	Description	Outcome
1. Familiarizing ourselves with the data	Transcribing data, translating transcripts, reading and rereading transcripts, making notes on initial ideas	• Case description • Phases of DigitalGrid project (Figure 3) • Ideas for subsequent steps
2. Generating themes	Themes chosen based on theoretical perspectives	• Themes: affordances, familiarity, totality
3. Generating initial codes	Codes generated and assigned to relevant themes, based on literature and previous steps	• Initial codes for each theme
4. Coding data extracts	Coding relevant and interesting features across the entire data set and adding new codes	• Additional codes • Coded data extracts
5a. Analyzing themes: *Familiarity and Totality*	Collating codes into themes, gathering data relevant to each theme; focusing on links among familiarity, totality, and affordance perceptions	• Codes connected to themes • Activities leading to familiarity and totality • Links among familiarity, totality, and affordance perception (Table 4)
5b. Analyzing theme: *Affordances*	Cycle 1: Identifying affordances from codes and data extracts Cycle 2: Checking codes against data extracts, combining affordances	• Codes connected to theme • Digital twin affordances (Figure 5 in Appendix B and Table 5 in Appendix C)

6. Producing report and developing theoretical model	Reviewing and validating; selecting extracts, illustrating findings, relating back to research objectives; integrating the concepts of familiarity and totality in developing an enriched theoretical model of the relational aspect of affordance perception	• Theoretical model (Figure 4)

In the first step, interviews were transcribed verbatim and translated from Norwegian to English to enable all researchers to engage in further data analysis. The translated transcripts, observational field notes, and archival documents were read and reread. This step enabled us to familiarize ourselves with the data, resulting in ideas for subsequent steps of analysis and a thorough understanding of the case and the phases of the DigitalGrid project (Figure 3). In the second step, we generated themes for further data analysis driven by our research objectives. We wanted to capture the digital twin affordances, and accordingly, we generated the theme *affordances*. Further, following our objective to explore how the two concepts of Heidegger could help explain and specify affordance perception, *familiarity* and *totality* were also chosen as themes for our data analysis.

The third step involved generating initial codes within each theme. The generated codes represented features of the data that appeared interesting and relevant to our research objective (Braun & Clarke, 2006), based on the literature and pre-understanding we developed through familiarizing ourselves with the data. For instance, codes could represent potential digital twin affordances, or they could be linked to the underlying ideas of familiarity and totality. Then, in the fourth step, we coded the data. Coding implies organizing the data into meaningful groups (Braun & Clarke, 2006) and collating data extracts into relevant codes. During the coding process, we also identified additional affordances than those we initially had considered, which generated new codes.

Regarding the fifth step, we chose different approaches to analyze the familiarity and totality themes and the affordance theme in parallel. For the familiarity and totality themes (step 5a), we first gathered and organized all coded data extracts for each code and accompanying theme. Our analytical focus here considered capturing relevant links between the digital twin totality and the users' familiarity and linking these to affordance perception. We reviewed the data extracts and codes for each theme several times with constant comparison among the data, codes, and themes to ensure we had captured the full essence of both themes. Based on this step, we were able to determine how users came to perceive digital twin affordances and link these insights to the users' familiarity and digital twin totality (Table 4). The affordance theme (step 5b) was analyzed in two cycles (see Figure 6 in Appendix B). First, we identified candidate affordances based on the codes and data extracts underlying the theme. Second, we reviewed and again checked the codes against the data extracts to combine and refine digital twin affordances. The affordances identified are described in detail in section 4.3 and summarized in Table 5 in Appendix C.

In the sixth and final step, we again studied the coded data extracts and themes in detail. Extracts, codes, and themes were reviewed and validated, and sometimes renamed or recombined. We then wrote down the story the data told. We chose relevant data extracts to include to capture the points we wanted to demonstrate, presented our findings with logical illustrations, revised these illustrations, and related the findings to our research objectives (Braun & Clarke, 2006), and in so doing, we integrated the concepts of familiarity and totality in an enriched theoretical model of the relational aspect of affordance perception.

4. Results of the Empirical Study

In this section, we present the results of our empirical study. First, we present the evolution of the DigitalGrid project through three phases, which represented a learning and maturing process for GridCo. Second, we show how this learning involved GridCo users developing a familiarity with the digital twin totality, which evolved through activities in the interplay between the users (GridCo) and developers (DigitalCo). This, in turn, enabled the users to perceive eight digital twin affordances, which are presented in the third subsection.

4.1 Evolution of the DigitalGrid Project

The DigitalGrid project began in early 2018 with a three-year projected duration. From the interviews and project documentation, we identified three main phases of the project evolution as summarized in Figure 3.

Phase 1 (2018)	Phase 2 (2019)	Phase 3 (2020)
• Establishing project details & formalities • Conducting idea-workshops • Mapping GridCo processes • Generating ideas • Identifying GridCo problems & needs • Creating visual prototype of twin • Sharing data vol.1 • Creating foundation for twin development	• Analyzing & managing risks (e.g. IT security) • Developing twin in sprints • Conducting sprint demonstrations • Sharing data vol.2 • Establishing twin (version 1 & version 2) Experimenting with features • Gaining some experience with twin	• Specifying needs & requirements • Suggesting specific features • Deploying twin to GridCo tenant (version 3) Sharing data vol.3 • Gaining rich experience with twin • Achieving strategic importance

FIGURE 3 DigitalGrid project evolution through three phases

The official kickoff of the project was on February 1, 2018; since then, the DigitalGrid project has evolved incrementally over time. In the first phase, when all formalities and project details were in place, DigitalCo engaged an agency to facilitate idea workshops with GridCo users to map processes, generate ideas, and identify the problems and needs of GridCo. Four workshops were conducted, which generated a broad list of requirements for the digital twin and the project. In the beginning of the second phase, GridCo was focused on dealing with IT security and finding viable solutions for sharing increased amounts of data with the twin. This was of particular importance because the energy sector in Norway is subject to regulations from the Energy Act to protect sensitive power system information. Once security measures were in place and risks were under control, the development of the digital twin could start. The developers at DigitalCo worked in two week sprints, where the latest status and updates on the digital twin were presented to GridCo users in sprint demonstrations on a monthly basis. The development approach in the second phase was explorative, characterized by experimentation and idea testing. Based on the list generated in phase one and feedback from GridCo users, DigitalCo added features to the digital twin on a continuous basis. The third phase was characterized by increased user-centricity, in that GridCo users became more specific in expressing their needs and requirements for the further development of the digital twin, which DigitalCo accommodated. As one GridCo respondent commented, "*It's kind of a way for us to take more control in the project, basically, and get the most out of the project. We just want our needs to be met*" (Respondent 1). Accordingly, driven by a fear of ending up with "*something that is fun, but not useful*" (Respondent 1), the GridCo users took a more active role in phase three, to ensure that the digital twin would in fact have features that could accommodate their problems. During the third phase, the digital twin was transferred to GridCo's tenant, allowing GridCo to expand the scale and scope of the data extracted to the twin without exposing sensitive power system information. During the third phase, the DigitalGrid project also received increasing attention from GridCo on a strategic level, with the top management pointing to the digital twin as an essential building block in GridCo's digital transformation.

During the project, valuable learning enabled GridCo users to more actively specify their needs for the digital twin along the way. One respondent from GridCo explained, "*I can only evaluate the functionality against my understanding. And the understanding has evolved during the project. And I also evaluate the functionality against our own needs. And the more I have talked to our people, and the longer I have worked in GridCo, the more I understand our needs. So it's an evaluation of our needs versus the twin's functionality"* (Respondent 1). The increased understanding also enabled GridCo users to gradually realize the value of a digital twin of the grid network: "*I would say that the understanding of 'what this is' has increased. And we realize more and more how things cohere, which we did not realize in the beginning at all. And we didn't know that we needed [a digital twin] when we started this project. So that is an understanding that has evolved over time"* (Respondent 6).

4.2 Familiarity with Referential Totality to Enable the Perception of Affordances

Building on Heideggerian thought, we found that affordance perception was possible because GridCo users developed a familiarity with not only the digital twin artifact and its features, but the totality of the digital twin. Familiarity constitutes the user's pre-understanding, embedded in know-how and related to specific contexts, providing the user with a readiness to cope with an artifact. By totality, we refer to the artifact's referential whole. In our case, familiarity with the digital twin totality implies the GridCo user's familiarity with three interrelated components of the digital twin: the tasks the user could perform with the twin in relation to other artifacts, the purposes behind applying the digital twin, and the identity the user could assume in this application. In this section, we present the activities and initiatives conducted throughout the project and those in the interplay between GridCo and DigitalCo that enabled GridCo users to develop familiarity with the totality of the digital twin, and how this, in turn, influenced the perception of artifact affordances.

Leveraging experience. Building on experience from developing digital twins in other industries, DigitalCo transferred knowledge, methodology, and frameworks to the DigitalGrid project and the grid sector. As one representative from DigitalCo explained, "*We draw from synergies regarding technology and methodology from other industries or other domains, such as oil and gas and the maritime sector. So we build on coding-related and methodological elements from other parts of our organization*" (Respondent 20). DigitalCo illustrated what they had accomplished with digital twins in other industries, which helped GridCo users imagine for what purposes a digital twin of the grid network could potentially be applied.

Involving users. DigitalCo consistently involved GridCo users in the development and design of the digital twin. The users who were involved in the DigitalGrid project mainly represented employees from departments for which the digital twin had the greatest potential of application: the Operations (i.e., those working on operating and maintaining the grid network in the short term) and Development (i.e., those working on maintaining and developing the grid network over the long term) departments. In addition, some employees from the Innovation and IT departments were part of the project team. As such, "GridCo users" consisted of employees who had extensive knowledge about the grid network structure and data, as well as grid company processes, and as such, already had familiarity with the physical counterpart of the digital twin. For DigitalCo, user involvement was crucial to ensure they developed something of value and utility for GridCo. In addition to regular meetings and continuous dialogue, DigitalCo involved GridCo users in the development and design of the digital twin in three ways. First, the users were actively involved in the idea workshops in the first phase. Here, GridCo's "*problems and needs for the short and long term*" (Respondent 3) were identified, which became the guide for the development of the digital twin. Second, GridCo shared relevant grid network data with DigitalCo to develop the digital twin. Third, GridCo users attended the sprint demonstrations where DigitalCo presented the status of the digital twin development and where GridCo users provided feedback and input. This heavy involvement enabled the users to develop an understanding of the digital twin technology and also to "*see the digital twin in relation to other things, other work and projects in the company"* (Respondent 3).

Visualizing. Through different types of visualizations, DigitalCo was able to show GridCo users for what purposes the digital twin could be applied. In the beginning, visualization was mainly done through pictures and slideshows. Later in the project, however, DigitalCo could show the actual digital twin solution to the GridCo users, which made it easier for the users to imagine what the digital twin could be used for and provide relevant input to the developers. According to GridCo, visualization was essential: "*In the beginning everything was just on paper. And then DigitalCo made some sort of mockup, which made it more realistic. And the more functionality we can see, the easier it is to relate to the twin and other possibilities. It's hard to only discuss with words. It's easier for the users to see, and provide feedback on adjustments, when there is something concrete to relate to*" (Respondent 22).

Testing. Eventually, GridCo users obtained the access to test and use the digital twin during the project period, as the different versions of the digital twin were released. This access was groundbreaking for GridCo, as it increased the users' "*knowledge of the twin's areas of application*" (Respondent 8). Accordingly, the opportunity to test and "*play around*" (Respondent 19) with the twin increased GridCo users' familiarity with it and potential areas of application. As one respondent explained, "*There's something that happens when you get to click inside the digital twin and start a process . . . And that's when we start asking questions regarding data quality, whether calculations are correct, or if we could add* '*this and that*'" (Respondent 1).

Standardizing design. The digital twin was a georeferenced, digital representation of the grid network in GridCo's concession area. Through a map-based application, GridCo users could recognize their entire grid network, digitally, with all its components and properties. This was possible for two specific reasons. First, the digital twin was based on GridCo's data and grid network. Second, DigitalCo developed and refined the graphical user interface of the digital twin based on feedback from GridCo users and grid sector standards. As one GridCo respondent explained, the digital twin was built on "*a standardized information model where voltage is voltage, and electricity is electricity—so that you can compare apples with apples and bananas with bananas*" (Respondent 1). Further, the digital twin features in the insight, planner, optimizer, and health categories were readily available for GridCo users with familiar tools and logical graphical interfaces; thus, they could become familiar with the tasks possible to perform with the digital twin.

Challenging. The tasks GridCo users could perform with the digital twin were linked to a set of purposes to which these tasks were put. Familiarity with the purpose component of the totality implied understanding the challenges GridCo faced as a grid company and the issues and problems GridCo users had which the digital twin could accommodate. Although GridCo was aware of their challenges and issues, DigitalCo was able to emphasize the severity and imminency of these challenges, and also demonstrate to GridCo users how they could apply the twin to accommodate them. As one respondent from GridCo explained: "*We need to know which means we can use to ensure our customers' needs are fulfilled, and at the same time sustain the balance in the grid network. So we need to look at all these means, and how we apply them to always ensure that our customers are satisfied and they get their electricity at the right quality. That voltage levels are sustained. And to do so, we need the digital twin*" (Respondent 8).

Mapping. The final component of the totality was the identity GridCo users could assume in applying the digital twin to perform purposed tasks. In this case, this implied the identity of the main user groups at GridCo who would potentially apply the digital twin: operations and development. Familiarity with the identity evolved through GridCo and DigitalCo making efforts to identify and map the tasks and processes of the user groups. Considering existing processes and how they could be improved to get where they wanted to be, GridCo users developed a familiarity with the identities of *improved operations* and *improved development* that they could assume in performing tasks with the digital twin. Accordingly, familiarity with the identity component of the digital twin evolved through an understanding of how the digital twin could improve the operations and development processes and tasks.

To summarize, through leveraging experience, involving users, visualizing, testing, and standardizing design, the project enabled GridCo users to develop familiarity with the digital twin, its features, and how they could apply it. Application of the digital twin was further linked to the purpose behind GridCo users applying the twin and the identity they could assume in doing so. GridCo users developed familiarity with purpose and identity through DigitalCo challenging them and extensive mapping of tasks and processes.

4.3 Perceiving Digital Twin Affordances

Eight digital twin affordances were identified in this study as perceived by GridCo users, each of which was formulated as an "*ability*" because they represented action possibilities offered to users in relation to the digital twin. A summary of the digital twin affordances is provided in Table 5 in Appendix C.

Collatability refers to the possibility for GridCo users to use the digital twin to collate and combine data from several sources. One GridCo respondent explained that, with the digital twin, they were "*able to collate different types of data, and get insight into things that are not possible in our traditional professional systems, where we only have one perspective*" (Respondent 22). He continued, "*with the digital twin, we can link several perspectives, and feed the twin with different input, to get more accurate answers*" (Respondent 22).

Monitorability regards the possibility for GridCo users to apply the digital twin to monitor the grid network and its health status and identify bottlenecks and voltage discrepancies. One GridCo respondent explained, "*[The digital twin is] able to always update us on the level of risk in the grid network, based on ongoing work on the grid, weather and wind, and condition evaluations in the grid network . . . We can monitor which areas of the grid network are most critical today, regarding outages and incidents"* (Respondent 3).

Operatability refers to GridCo users' possibility to operate the grid network through the digital twin, supporting planning and maintenance in the short term. Being fed with relevant and real-time data from sensors in the grid network and other data sources, the digital twin is able to present the grid network with all its components in an understandable and accurate way, which makes the digital twin "*central as a tool for operational support*" (Respondent 1). This affordance is mainly actualized by the Operations user group, that is, "*those who have a need for insight into how the grid is going to behave 48 hours ahead in time*" (Respondent 1).

Developability concerns GridCo users' possibility to develop the grid network through the digital twin, supporting planning and investments in the grid in the long term. This affordance is mainly actualized by the Development user group, that is, "*those who are supposed to have control over our grid network*" (Respondent 19). In the digital twin, the users can analyze consequences of changes in the grid network, and based on the output from the twin, they can evaluate the best viable option for further grid development.

Simulatability refers to the possibility for GridCo users to apply the digital twin to simulate different scenarios in the grid network. Feeding the twin with relevant and real-time data from several sources improves its simulation capacity. As one DigitalCo employee pointed out, "*the whole magic in this is what you feed it with, and how you orchestrate it, basically"* (Respondent 21). Accordingly, the digital twin can be used to simulate almost any scenario the users wish, as long as the twin has the necessary data available to do so. According to GridCo, this affordance is particularly important because of the aforementioned changes in the grid sector, with new consumption and production patterns predicted to come in the future.

Decision supportability regards the possibility for GridCo users to use the digital twin for support in decisions regarding the grid, where the digital twin suggests solutions for handling issues in the grid network. Again, the more data the digital twin is fed, the better the decision support: "*When you are making decisions; the more information you feed it with, the more perspectives you get, and the better decisions you can make*" (Respondent 8). The digital twin can support GridCo users in decisions in both the short and long term, that is, in operating the grid on a daily basis (Operations) and in developing the grid network (Development).

Automatability refers to the possibility for GridCo users to apply the digital twin to automate tasks, processes, and decisions. As one person at GridCo noted, the dream is, put bluntly, that "*everything is automated*" (Respondent 19). One respondent from GridCo explained how they "*do a whole lot of manual processing around here, which I believe the digital twin could relieve through automaton*" (Respondent 22). He continued, "*It's not enough that data flows one way only. The digital twin will have to be able to make automatic reconnections, or make adjustments in the real world to solve the problems that the digital twin finds. This has to happen, or else we'll just get a new warning lamp somewhere, and we'll have to go into a different system to fix it."*

Customer improvability refers to the possibility for GridCo users to use the digital twin to improve the customer interface and the way they approach the customers by simplifying and automating customer interactions and processes, integrating digital twin applications with the customer interfaces, and even "*provid[ing] the customers with self-service solutions*" (Respondent 1). By doing so, GridCo users argued, they could rely on fewer actors in the customer processes, respond to customers more quickly, and reduce costs.

Table 4 illustrates the perceived affordances and how GridCo users developed familiarity (i.e., through which activities) with each of the different elements of the totality of the digital twin (i.e., tasks, purpose, and identity).

TABLE 4 Perceiving digital twin affordances

Perceived digital twin affordance	**Familiarity of digital twin tasks based on features**	**Which was developed through**	**And familiarity of purposes (developed through Challenging)**	**And familiarity of identity (developed through Mapping)**
Collatability	• Open information model	• Leveraging experience • Involving users • Standardizing design	GridCo challenges and user issues	• Improved operations • Improved development
Monitorability	• Insight • Health	• Leveraging experience • Involving users • Visualizing • Testing • Standardizing design	GridCo challenges and user issues	• Improved operations • Improved development
Operatability	• Planner	• Leveraging experience • Involving users • Visualizing • Testing • Standardizing design	GridCo challenges and user issues	• Improved operations
Developability	• Planner • Optimizer • Health	• Leveraging experience • Involving users • Visualizing • Testing	GridCo challenges and user issues	• Improved development
Simulatability	• Open information model • Planner • Optimizer	• Leveraging experience • Involving users • Visualizing • Testing	GridCo challenges and user issues	• Improved Operations • Improved Development
Decision supportability	• Open information model • Insight • Planner • Optimizer • Health	• Leveraging experience • Involving users • Visualizing • Testing	GridCo challenges and user issues	• Improved operations • Improved development
Automatability	• Planner • Optimizer • Health	• Leveraging experience • Involving users • Visualizing • Testing	GridCo challenges and user issues	• Improved operations • Improved development
Customer improvability	• Insight • Planner • Optimizer • Health	• Leveraging experience • Involving users • Visualizing • Testing	GridCo challenges and user issues	• Improved operations • Improved development

In sum, familiarity with the digital twin totality enabled GridCo users to perceive the digital twin affordances. Without this familiarity, digital twin affordances could have remained latent or hidden for the users. To illustrate with an example, the users who developed a familiarity with the digital twin and its totality were involved in the development of the digital twin. This involvement enabled them to develop familiarity with the digital twin totality. However, other employees at GridCo lacked this familiarity, and hence would not perceive the digital twin affordances. Accordingly, expanding the scope of users and user groups involved in the digital twin development could potentially lead to additional affordances being perceived. Further, DigitalCo talked of a ninth digital twin affordance—*Flexibility*

Manageability—the possibility of managing flexibility solutions in solving capacity challenges from an operational perspective. According to one DigitalCo user, this was the affordance they "*actually have the most faith in*" (Respondent 20); however, they acknowledged that GridCo users had not developed enough familiarity with the digital twin totality, particularly the potential purposes behind applying the digital twin, for them to perceive this affordance.

5. Discussion

Our study started with the objective of unfolding the relational view of affordances and how this would influence the perception of affordances. We applied the Heideggerian concepts of familiarity and referential totality. The perception of affordances does not happen in isolation; rather, as Heidegger expressed, actors are "being in the world"; they have familiarity with the objects based on their everyday engagement in the world. They perceive the action possibilities of the object in its referential totality. In the previous section, we discussed how our empirical study of GridCo enhanced our understanding in this regard. In the following section, we discuss threefold contributions of our study to the theory of affordances.

5.1 Specifying the Relational Aspect of Affordances

Our study shows how GridCo users' familiarity with the *tasks* and everyday use of the digital twin evolved as a result of DigitalCo leveraging their previous experience with digital twins and involving GridCo users in the development of the digital twin. These efforts on DigitalCo's side were found to be important contributors to GridCo users perceiving all eight identified digital twin affordances. For each of the affordances identified, users' familiarity with the tasks they could perform with the digital twin was reinforced through additional activities throughout the project and in the interplay between DigitalCo and GridCo. For instance, through visualizations of the digital twin, as well as GridCo users' opportunity to test and use the digital twin during the project evolution, the users developed an understanding of how they could apply the digital twin to simulate different scenarios in the grid network (i.e., simulatability) and further develop the grid network (i.e., developability). Because the digital twin was designed based on grid sector standards, GridCo users were further able to recognize both the physical grid network and the tools available for them in the digital twin to understand how the twin could be applied in everyday use, for instance, to monitor (i.e., monitorability) and operate (i.e., operatability) the grid network.

Familiarity with the everyday use and tasks to perform with the digital twin was not enough for the users to perceive digital twin affordances. As our case showed, affordance perception only occurred when the users had familiarity with all the elements of the digital twin totality: tasks, purpose, and identity, which was not the case for the ninth affordance that DigitalCo had envisioned (i.e., flexibility manageability). Regarding *purpose*, understanding of the purposes behind the application of the digital twin evolved with the users as they were challenged by DigitalCo to thoroughly think through the grid company's challenges as well as issues they were faced with in their daily practices. After the extensive mapping of grid company processes, the users became more familiar with the *identities* they could assume in applying the digital twin to perform purposed tasks and to improve grid operations and development.

In sum, through the project evolution and interplay between the users (GridCo) and designers (DigitalCo), the users developed familiarity with the digital twin totality and were able to perceive eight digital twin affordances. Without familiarity of the artifact totality, users would not have perceived the affordances offered in relation with the digital twin (i.e., affordances would remain latent), as would have been the case for other GridCo employees who were not involved in the development of the twin, did not get the opportunity to test the digital twin prototype, had not thought through the grid company's challenges, were not engaged in process mapping and improvement, and so on.

Drawing on these insights, we developed an enriched theoretical model integrating the concepts of familiarity and referential totality to present a nuanced perspective to specify the relational aspect of affordance perception (see Figure 4).

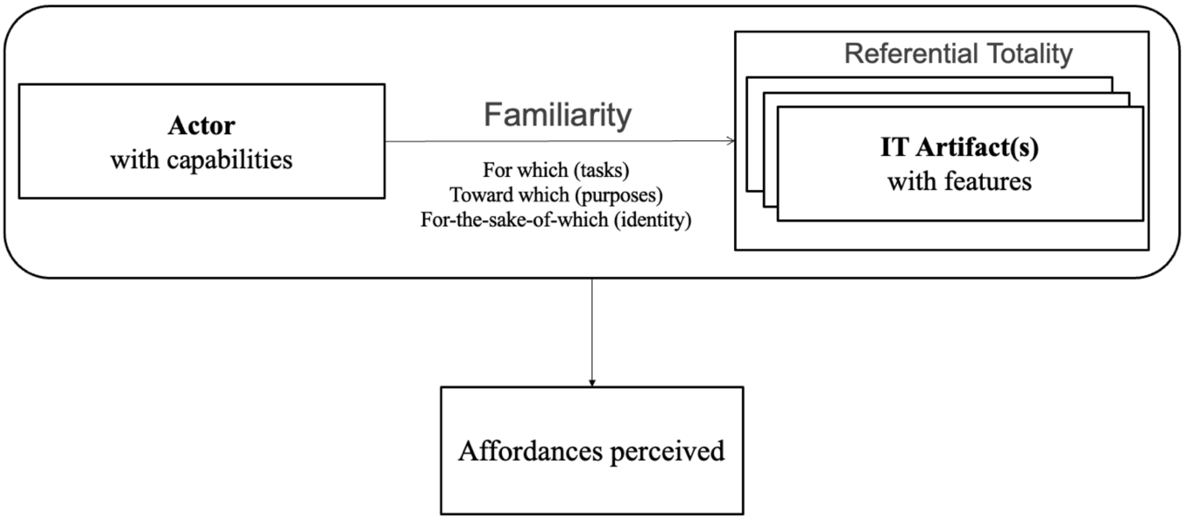

FIGURE 4 Nuanced perspective on relational aspect of affordance perception

In our model (Figure 4), the actor and IT artifact are placed as part of the same "world," where the actor becomes familiar with the artifact totality. We continue the general perspective that affordance perception requires an actor with capabilities and goals; however, by integrating Heideggerian concepts, we seek to illustrate that the relation in which affordances arise is not as simple as the relation between the actor (with capabilities and goals) and the artifact (with features). Rather, affordances arise from the familiarity of capable and goal-directed actors with the artifact in totality (since every artifact is part of a larger totality). In other words, we posit that an actor perceives affordances in relation to an artifact if the actor is familiar with the totality of the artifact. This implies that the actor, for one, is familiar with the everyday use of the artifact rather than characteristics and features of the artifact as well as which tasks the actor could perform with the artifact (i.e., with how the artifact reveals itself in practice and in connection to other artifacts). Second, the actor is familiar with and understands some purposes to which these tasks can be put, and third, which identity the actor could assume in performing them.

Familiarity considers context, cultural background, and norms, in that the actor perceives affordances based on their background understanding and everyday know-how in relation to an artifact in a particular situation in a given context. Familiarity, as such, represents a shared background understanding of a shared world—a phenomenon containing any contextual element of practical everyday life (Dreyfus, 1998). Hence, an actor's familiarity with the referential totality of the artifact can enable the actor to perceive affordances.

5.2 Providing Valuable Insights into Affordances of Digital Twins

The digital twin is an emerging phenomenon, and research on it is still nascent (Kritzinger et al., 2018). Hence, our work contributes to IS research in exploring how such complex digital artifacts are understood and applied by users in specific contexts. Moreover, our study contributes to the literature on digital twins by illustrating which affordances arise in the relation between a digital twin and users, and how and why these affordances are perceived by users. Also, our study illustrates the important role a digital twin can play in firms' digital transformation, in particular for incumbent firms such as GridCo.

We identified eight digital twin affordances perceived by the users: collatability, monitorability, operatability, developability, simulatability, decision supportability, automatability, and customer improvability. Some of these affordances are in line with the predictions of digital twins enabling companies to operate, monitor, and develop their physical counterparts as well as serving as valuable tools for simulation and decision support (Enders & Hoßbach, 2019; Madni et al., 2019). Moreover, our study also illustrates that digital twins can serve as helpful tools in collating dispersed and increasing amounts of data in the physical counterpart's environment, automate tasks and processes, and improve customer support, all of which are valuable for incumbent firms' digital transformation and to stay competitive and relevant in the digital era. However, for any of these affordances to become a reality and the potential of a digital twin to avoid remaining untapped, the users of a digital twin need to become familiar with the features and tasks to perform with it, the purposes behind performing these tasks, and the identity they could assume in doing so. In other words, users and their digital twins need to be in the same "world" to become familiar with the referential totality of the digital twin.

5.3 Explaining the Mechanisms That Develop Familiarity with Totality

With our study, we not only expand and specify the relational aspect of affordance perception through integrating the Heideggerian concepts of familiarity and totality; we also explain the mechanisms which should be in place for users to develop familiarity with the artifact totality (Table 4). Our findings also show that the users of digital twins, unlike the physical structure (grid network), need two levels (physical and virtual) of familiarity and pre-understanding of the totality to perceive its affordances.

This understanding also addresses the confusion of the relational aspect of the theory of affordances. The relation in existing research has been interpreted in different ways (Lanamäki et al., 2016). We argue that the relation should not be understood through interaction and reflections but through engagement and action based on familiarity with the totality. That comes from our everyday engagement in the world.

There is some evidence in our case study that, as GridCo users' familiarity with the referential totality of the artifact increased, the users gradually came to experience the application of the digital twin as being of significance and contributing to achieving GridCo's digital transformation goal to optimize resources and increase customer satisfaction. This was also reflected in GridCo management's gradually increasing devoted attention to the digital twin and DigitalGrid project on a strategic level. This significance was further reinforced through DigitalCo actively trying to engage GridCo users in understanding the sense-of-urgency of grid sector challenges and the relevance of the digital twin to accommodate these challenges. Particularly, the affordance regarding automation of tasks, processes, and decisions (i.e., automatability) was perceived by the GridCo users and was considered as technically possible to act upon; however, the users did not yet evaluate this affordance as significant enough for them to actualize it. Hence, this suggests that, for a final digital twin to be rolled out as a company-wide digital solution, it must be clearly linked to the digital transformation goal of the company, so that the general employee would evaluate their application of the twin in their everyday practice as of significance. Otherwise, the digital twin's potential would remain untapped.

Although we mainly focused on the actor–artifact relation in this article, our empirical study also revealed that, in cases of high levels of user involvement in developing and designing an IT artifact, the designer can play an important part in influencing the user's familiarity with the totality of the artifact. As such, the designer can contribute to the user's perception (and potential actualization) of affordances, not only through design (i.e., designed affordances; Lanamäki et al., 2016), but also through interacting with the user throughout the development period. By involving intended users throughout the development and design of the artifact, the users and designers are more likely to develop the same understanding of the artifact and its potential applications. Put differently: if the designer and actor are part of the same "world," this increases the likelihood of affordance perception.

For developers specifically, our study provides detailed insights into how to ensure the intended users actually understand (and eventually use) a digital artifact (e.g., a digital twin) as intended by the developers. Our model suggests familiarity with artifact totality as a necessary condition for users to reveal action possibilities, and our case study illustrates how this could be ensured, which should be taken into consideration when developing digital artifacts. We found that designers could contribute to the user's affordance perception through heavy user involvement and visualization, allowing the user to test the application, standardizing the design of the artifact, challenging the user, and extensive mapping of the user's tasks and processes. Furthermore, when developing complex digital artifacts, such as a digital twin, it is important to consider co-creation together with a developing party who has relevant experience. Actively engaging in the design and development of the artifact would further enable the company to influence the final solution, ensuring their needs and wishes are met and that the artifact and its application are aligned with overarching organizational goals.

6. Conclusion

In this paper, we addressed the relational aspect of affordances and sought to specify and expand our common understanding of how actors come to perceive affordances. Existing views of affordance perception are diversified and unclear and seem to consider actors as working in isolation and interacting with artifacts to achieve their goal. Building on Heidegger's philosophical thinking, we have developed an enriched theoretical model and argued that actors are already embedded in the "world" with artifacts and perceive affordances in everyday practice. In this world, the actor becomes familiar with the artifact totality, which enables them to perceive affordances offered in relation to the artifact. This implies that the actor, in being in the world, develops an understanding of the features and tasks to perform with the artifact, the purpose of performing these tasks, and the identity the actor could assume in doing so. In our case study, we showed how GridCo users over time developed this familiarity with the digital twin totality, which enabled them to perceive digital twin affordances.

As with every study, our work also has limitations. For instance, we borrowed the concepts familiarity and totality. We acknowledge that Heidegger's philosophy and thinking are complex, and that the complexity of the concepts is greater than how we have portrayed them in this paper. However, understanding and explaining all of Heidegger in detail would require an entirely different study. We believe we have captured the essence of familiarity and totality through our application of the concepts. Moreover, to achieve high reliability and to exclude confounding variables introduced by the heterogeneity of organizational contexts, we focused on only one company. In that sense, we bought internal consistency at the expense of generalizability. Also, the digital twin in our empirical study is currently only a prototype and part of a research and development (R&D) project involving DigitalCo, GridCo, and other partner companies. The full digital twin solution will only be available for GridCo and other grid companies if they choose to acquire the solution when the project ends, which is most likely but not certain.

As we have focused on affordance perception, future research should investigate the actualization of affordances and how Heideggerian concepts may also provide a nuanced perspective in that context. In the particular case of a digital twin of the grid sector, future research could expand the outcomes and goals to an even broader perspective, such as contribution to sustainable development goals (SDGs). Our theoretical model should be further tested in other domains and with varying types of actors and artifacts to explore its tenability. In addition, future research could also investigate the role of the designer in influencing affordance perception and actualization as being part of the same “world” as potential users.

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Appendix A: Interview Guide Example

Introduction (our research interests)

The respondent's role in the DigitalGrid project (if applicable)

- Could you specify your role in the project?
- How and when were you introduced to the project?
- What are your main tasks related to the project?
- Have your tasks or role changed during the project?

Phases of the DigitalGrid project

- GridCo respondents:
    - How has the DigitalGrid project evolved over time?
    - My impression is that the DigitalGrid project has evolved over time through different phases: In 2018 the focus was on generating ideas, in 2019 the focus was on experimenting and exploring functionality of the digital twin, and in 2020 the focus has been on specifying the needs of GridCo and functionality of the twin more concretely. Does this perception relate to your understanding of the development of the DigitalGrid project?
        - If yes/no: Could you elaborate?
    - Specification of different project phases:
        - What are the outcomes of each phase?
        - What have you learned from each phase?
        - Have your requirements to the digital twin changed during these phases?
- DigitalCo respondents:
    - How has the DigitalGrid project evolved over time?
    - Is it correct to infer that the DigitalGrid project evolution can be characterized by three different phases: In 2018 the focus was on idea generation, in 2019 the focus was on experimentation and explorative development of functionalities, and in 2020 the development will be more focused towards the grid companies' direct needs and specifications?
        - If yes/no: Could you elaborate?
    - Specification of different project phases:
        - What are the outcomes of each phase?
        - What have you learned from each phase?
        - Have your intentions with the digital twin changed during these phases?
    - Has the effort DigitalCo has put down in the project varied during the course of the project?
        - If yes; when and how has it changed?

Functionalities of the digital twin over time

- GridCo respondents:
    - What are the most important functionalities of the twin, in your perception?
    - Have your requirements to the functionality of the twin (what the twin is able to do) changed
        - If yes; why and what has changed?
    - What are the main drivers behind the requirements/functionalities of the digital twin?
    - Are your requirements of the functionalities of the twin in line with DigitalCo's intention of the digital twin?
- DigitalCo respondents:
    - What are the most important functionalities of the twin, in your perception?
    - Have your intentions of the digital twin and its functionalities changed during the course of the project?
        - If yes; why and what has changed?
    - What are the main drivers behind the functionalities and design of the digital twin?
    - Are your intentions of the digital twin functionalities in line with the grid companies' perceptions?

User-involvement

- GridCo respondents:
    - How much are you as a grid company and potential user of the digital twin involved in the development and design of the twin?
    - What are the main benefits of participating in the development and design of the twin?
    - Are there any challenges with being involved in the design and development of the twin?
- DigitalCo respondents:
    - What is the intention behind involving grid companies, like GridCo, in the development of the twin?
    - Has GridCo been involved at different degrees during the project? Or has their involvement been the same over time?
    - What are the benefits of involving the grid companies in the design and development of the digital twin?
    - Are there any challenges of involving potential users to this degree?

DigitalGrid objectives

- The project end-date is set to 01.01.2021. What do you hope to have achieved by this date?
- What are the next steps after this date?
- What are the main objectives of participating in the DigitalGrid project?

Appendix B: Data Analysis Affordance Theme

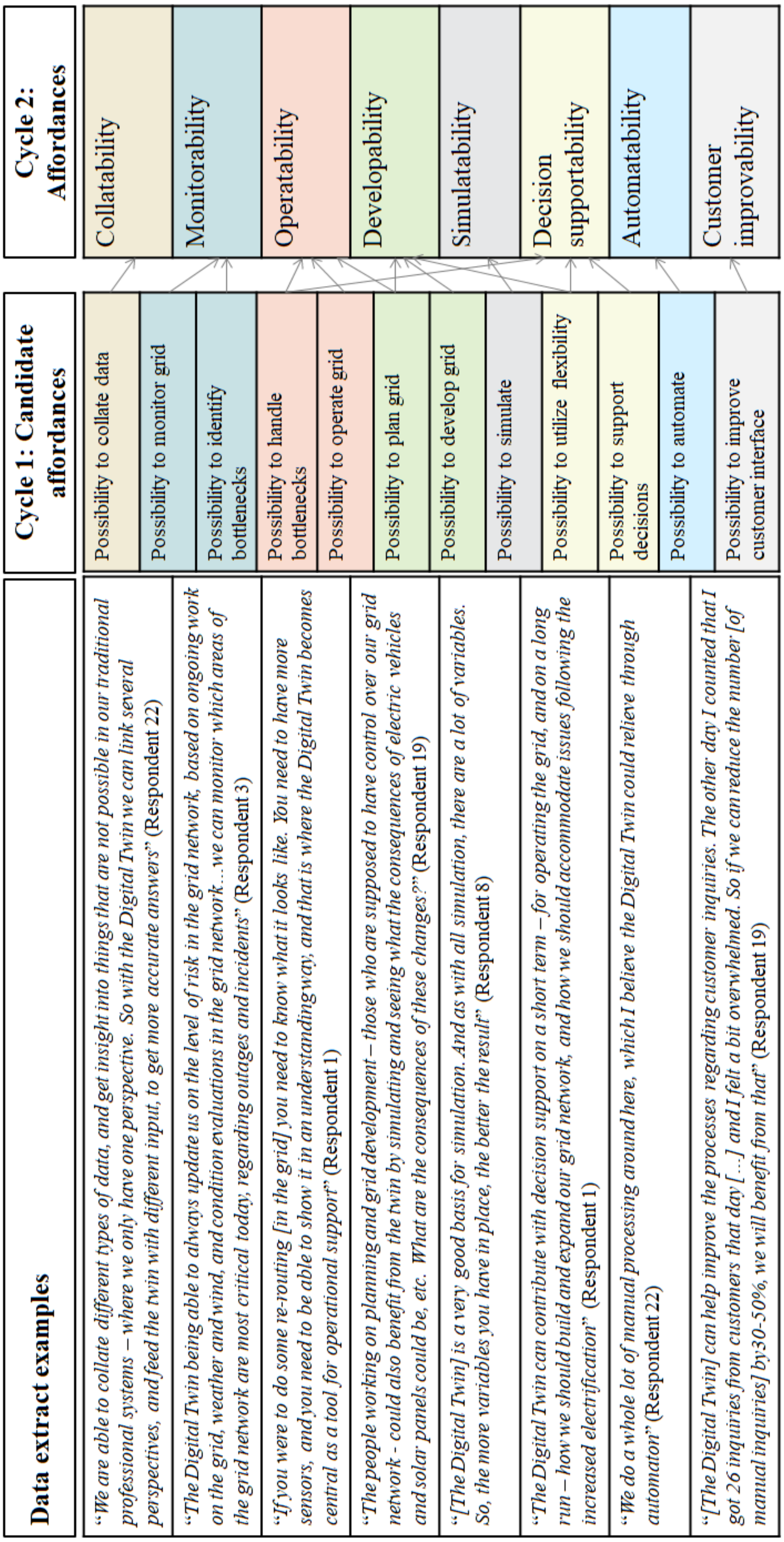

Figure 5 Data analysis affordance theme

Appendix C: Summary of Digital Twin Affordances

Table 5 Digital Twin affordances summary

Affordance	Description
Collatability	Possibility to collate and combine data from different sources (internal and external)
Monitorability	Possibility to monitor the grid network, its health status, and identify bottlenecks
Operatability	Possibility to operate the grid network and support planning and maintenance on a short term
Developability	Possibility to develop the grid network and support planning and newbuilds on a long term
Simulatability	Possibility to simulate for different scenarios in the grid network
Decision supportability	Possibility to support decisions regarding the grid, suggesting solutions for handling issues in the grid
Automatability	Possibility to automate tasks, processes, and decisions
Customer improvability	Possibility to improve the customer interface and approach by simplifying and automating customer interactions and inquiries

Article 4

Title: Co-creating a digital twin for the energy sector

Authors: Christian Meske, Karen Osmundsen, & Iris Junglas

Under review at journal: MISQ Executive

Abstract: Digital twins, exact replications of physical assets, are seen as next generation components and enablers of digital transformation. We showcase for a Norwegian grid company and its tech companion how co-creation was a prerequisite for the successful pairing of a physical grid infrastructure with its virtual counterpart. Moreover, the three-year and 8 million USD development project highlights that as a side-effect, digital twin projects inevitably lead to a deep reflection of existing competencies, routines, and the business model itself, thus uncovering crucial potential for innovation and repositioning in the market.

Keywords: *digital twin, co-creation, digital transformation, grid company*

"We are building a road here. We're not just driving up the road—we're building it along the way"
(Respondent 1, GridCo).

Introduction

For companies it is ever more important to gain real insights into customer needs and desires when creating relevant and suitable products and services. However, pervasive digitalization and complex technologies are constantly changing customer demands and requirements. The energy sector is one such industry that is currently facing major pressures. Renewable energies and their associated distributed production patterns, climate changes and extreme weather situations, and the advancements of automated meter reading (AMR) challenge established, load-balanced, and aging grid infrastructures. As a result, the entire system of producing, distributing, storing, and consuming energy is changing, stirring up established industry convictions.

In this context, co-creation offers a user-centered approach to innovation, where companies engage with their customers to assume more active roles in creating value together. By acknowledging the value and knowledge base of customers and providing a fruitful room for engagement, a company can bypass guessing customer needs and while doing so reduce the risk of developing products and services that are of no utility for the customers. Both the company and their customers learn together and from one another, allowing for innovation to take place. They nourish ideas, define problems, and create solutions *together*.

What started with AMRs, allowing grid companies to collect real time data on energy consumption, has, over time, already been combined with other sensor technologies. As a result, grid companies are provided a richer and more accurate informational base for monitoring and balancing the grid network. In fact, the latest technological advancements have the ability to transform grids into *smart grids*: grid networks coupled with information systems and digital technology.[1] In this context, "digital twins" represent a special class of smart technologies that integrate the physical and digital, coupling physical objects to virtual counterparts, and leveraging the benefits of both the physical and virtual

[1] Kettunen, P., & Mäkitalo, N. (2019). Future smart energy software houses. European Journal of Futures Research, 7(1), 1-25.

environments.[2] Allegedly, digital twins are key components in, or enablers of, digital transformations.[3] But digital twins are rare, and their successful development remains a mystery.

In this paper, we will show how co-creation was a vital ingredient for the development of a digital twin in the Norwegian energy sector. Specifically, we follow “GridCo” that, together with its tech companion “DigitalCo”, undertook a digital twin initiative which we have called “DigitalGrid”; an 8.3 million USD project which ended up being GridCo’s single most important initiative to preempt the changes of the energy sector. We will explore how co-creation was a prerequisite not only for the successful development of the digital twin, but also for maturing both organizations along several dimensions.

Digital Twins - A New Breed of Technology as a Vehicle for Co-Creation

Over two thirds of companies that have implemented or are planning to implement Internet of Things (IoT) initiatives are predicted to leverage digital twin technology. The concept of a “twin”, or the exact replication of an object, was originally introduced by NASA’s Apollo program in the 1960s, where two identical space vehicles were designed—one that went to the moon and the other one remaining on earth. The first mention of a “digital twin”, in contrast, was made by Michael Grieves in 2003 as part of a university course on Product Lifecycle Management.

As a concept, a digital twin can be understood as a virtual counterpart of an organizational asset that enables companies to digitally mirror and manage that asset along its complete lifecycle.[4] The pairing between the physical and the virtual allows monitoring the physical asset, often in real-time, analyzing its historical data points and using them for predicting future workings of the asset. In general terms, a digital twin consists of three major components: (1) a physical object in real space, which can be tangible or intangible, (2) a virtual object in virtual space (e.g., in the cloud), and (3) connections between the virtual and the physical space, tying the physical and virtual together.[5]

[2] Jones, D., Snider, C., Nassehi, A., Yon, J., & Hicks, B. (2020). Characterising the Digital Twin: A systematic literature review. CIRP Journal of Manufacturing Science and Technology, 29, 36–52.
[3] Saracco, R. (2019). Digital Twins: Bridging Physical Space and Cyberspace. Computer, 52(12), 58–64.
[4] Dietz, M., & Pernul, G. (2020). Digital Twin: Empowering Enterprises Towards a System-of-Systems Approach. Business and Information Systems Engineering, 62(2), 179–184.
[5] Grieves, M. (2014). Digital Twin: Manufacturing Excellence through Virtual Factory Replication. In Digital Twin White Paper (Issue March).

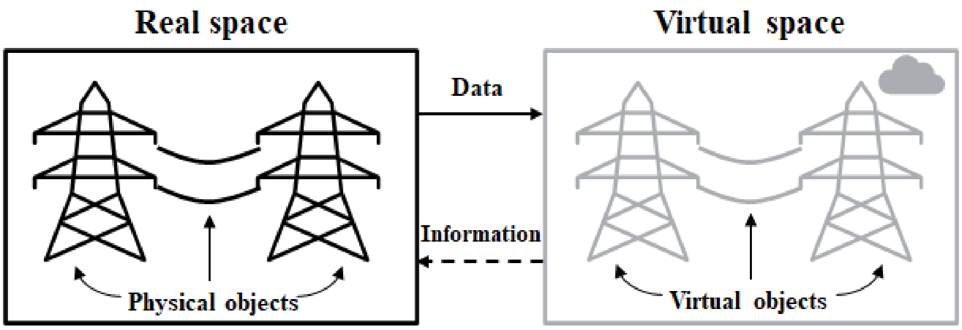

FIGURE 1. A DIGITAL TWIN MODEL OF A UTILITY GRID NETWORK (AMENDED FROM GRIEVES, 2014)

As Figure 1 illustrates, the physical object, a grid network tower for example, is equipped with sensors that generate a continuous data stream about its loading and capacity. These data points represent the virtual object and are collected by the digital twin who builds up a data repository over time and uses the data for a variety of analytical purposes. Monitoring the grid's status-quo, balancing its load, predicting faulty situations before they become reality, or running simulations, are just some of the analytical examples that a digital twin can perform. The ultimate goal of the digital twin is to send back information from the virtual to the physical object with recommendations for adjustments.[6]

At present, manufacturing is the most prominent industry using digital twin technology; others are only slowly following suit. Driven by the ability to keep track of physical assets, such as machines, machine parts and even manufactured products, the manufacturing industry mostly uses digital twin technology to mimic physical objects. But it is important to note that a digital twin is not merely a digital replication of a physical object. A digital twin is continuously updated with data from the physical object's performance throughout its life cycle. It also can perform functions that cannot be performed by the physical object alone, such as calculating its status-quo or predicting its impending failure.

Depending on the level of integration between the real and the virtual, variations of digital twins exist.[7] In a *real* digital twin, both physical and virtual objects are fully integrated and exchange data and information on an ongoing basis in a bi-directional way and without manual intervention. Put differently, the data sent by the physical object is used by the digital twin to generate courses of actions that are immediately fed back to the physical object. In a "digital shadow", on the other hand, the dataflow is

[6] Madni, A., Madni, C., & Lucero, S. (2019). Leveraging Digital Twin Technology in Model-Based Systems Engineering. *Systems*, *7*(7).
[7] Kritzinger, W., Karner, M., Traar, G., Henjes, J., & Sihn, W. (2018). Digital Twin in manufacturing: A categorical literature review and classification. *IFAC-PapersOnLine*, *51*(11), 1016–1022.

unidirectional only (from the physical to the virtual), and in a "digital model" the data exchange is manual.

Irrespective of its form, a digital twin is said to have multiple advantages. Apart from real-time monitoring of the behavior of physical objects, analyzing risks, scheduling predictive maintenance, planning for future upgrades and developments, and optimizing operations, digital twins have the potential to simulate scenarios and suggest solutions, which is particularly valuable for changing environmental conditions.[8] By enabling organizations to gain a rich, in-depth understanding of their physical assets, digital twins provide a comprehensive picture that reduces the downtime of the physical object. This is especially beneficial for organizations that operate critical infrastructures, such as grid companies.

Moreover, a digital twin can potentially be significant for organizations in transforming their business to stay relevant and competitive in the digital era and to unearth new business opportunities. As a key component in, and possibly even enablers of, an organization's digital transformation, a digital twin can play a vital role in an organization's strategic plan, particularly for those established asset-centric firms where data are scattered across separate organizational silos.[4]

The Digital Twin Project

The case organization, *GridCo*, is a grid company and large player in the Norwegian energy sector. GridCo is responsible for building, operating, and maintaining the regional and local grid network in a specific geographic area, to distribute electricity to customers. The company was founded in the early 1900s, has approximately 500 employees, and long traditions in serving their obligation to provide electricity to customers.

GridCo has ambitious strategic goals and is determined to pursue a large digital transformation program, which implies major changes to the entire organization, ways of working, and increased utilization of data and digital technology. The overarching goal of GridCo's digital transformation is to optimize all resources for the benefit of the customer, which refers to any industrial or private household within GridCo's concession area that consumes (or produces) electricity. Digital transformation for GridCo means optimizing both internal resources (e.g., human resources, data, technology) and energy sources within the grid network area (e.g., water, wind, sun, batteries).

[8] Enders, M. R., & Hoßbach, N. (2019). Dimensions of Digital Twin Applications - A Literature Review. AMCIS 2019 Proceedings, 1, 1–10.

One specific initiative that plays an important part in the digital transformation is the *DigitalGrid* project. In 2017, one visionary employee at GridCo was seated next to a representative from the software and digital solutions provider, *DigitalCo*, at a conference dinner. The two talked about an idea to develop a digital twin of the grid network in Norway, inspired by the recent developments of digital twins within other industries. Long story short, DigitalCo presented the DigitalGrid project to the management at GridCo, who were intrigued by the idea and decided to participate. Two other Norwegian grid companies joined the effort ("GridA" and "GridB"), along with two research institutes ("ResearchA" and "ResearchB") and one software provider ("SoftwareA") (see Figure 2). Since GridCo played the biggest role amongst the set, this study focuses exclusively on the relationship between GridCo and DigitalCo.

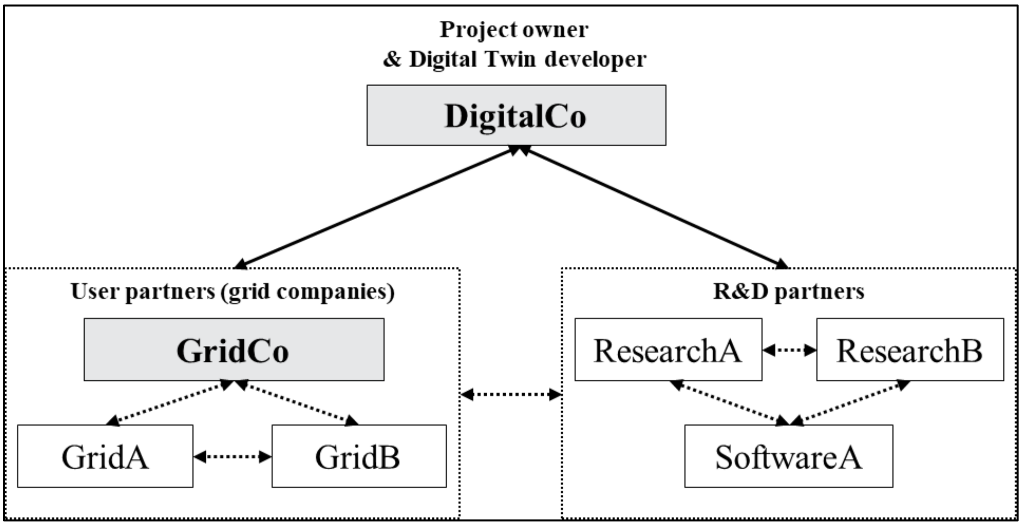

FIGURE 2: PROJECT STRUCTURE AND PARTICIPANTS

DigitalCo has a long history of technological innovations since its mother company was founded back in 1814. Driven by the increased digitalization in the offshore industry, DigitalCo was established as a subsidiary in 2016. Since then, the company has built its expertise with the development of digital twins, particularly in sectors such as oil and gas and maritime.

In the overarching structure of the project, DigitalCo was the designated project owner, responsible for developing the digital twin and leading the project. With its proven development environment and established position amongst industry partners, DigitalCo was able to utilize, and more importantly, transfer its experience of leading complex projects to the digital twin development for the grid sector.

As DigitalCo was new to the grid sector, they relied on user partners, like GridCo, to provide insights and grid expertise for analyses and verification, as well as specification of grid sector standards. User partners, apart from providing grid network data and processes, also contributed to the design of the digital twin. Representing potential end users of the digital twin, they provided feedback on features and graphical interfaces, as well as tested the usability of the solution. Apart from DigitalCo and its user partners, research institutions were part of the project composition. They provided insights from ongoing research activities, in particular relating to smart grid concepts and optimization algorithms used within different industries. For instance, in order to replicate the digital twin for the grid network, its underlying algorithms had to be adjusted to obey all electrical laws. Finally, the DigitalGrid project included one external software provider, whose main contribution was related to the data architecture underlying the digital twin.

The budget for the DigitalGrid project was calculated to be 70 million NOK (or 8.3 million USD) and was financed by contributions from the Research Council of Norway, Innovation Norway, from participating grid companies, including GridCo, as well as DigitalCo.

The DigitalGrid Project Evolution

The DigitalGrid project started early 2018 with a three-year time horizon in mind. Based on interviews and project documentation, three phases became apparent (see Figure 3).

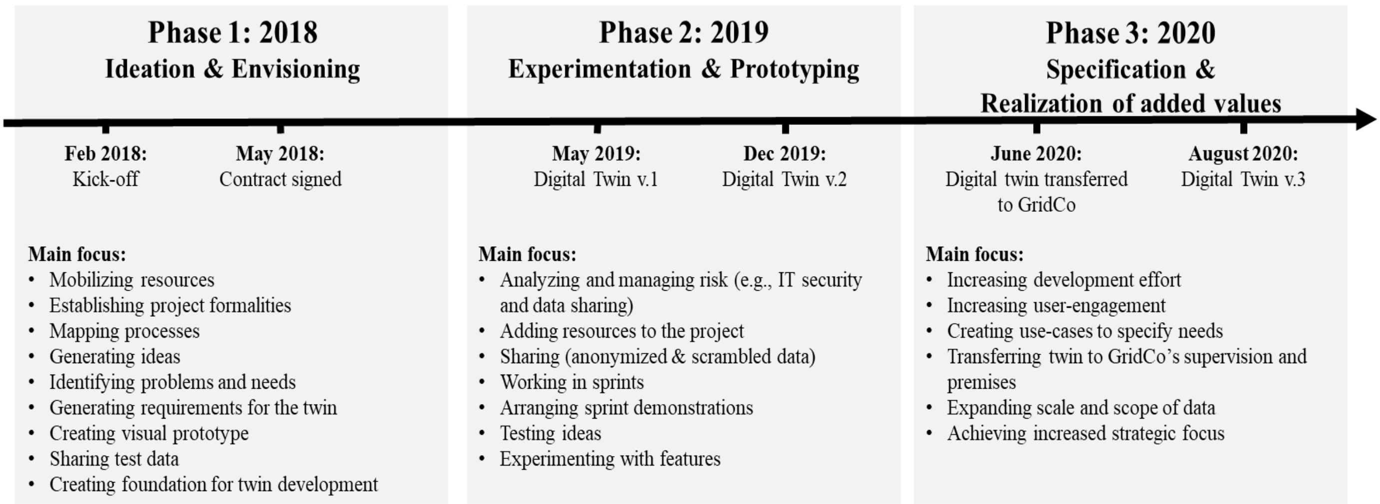

FIGURE 3. PROJECT EVOLUTION THROUGH THREE PHASES

Phase 1: Ideation and envisioning

Even though the DigitalGrid project had an official kickoff date of February 1st 2018, much effort had already been spent prior to this date, especially by DigitalCo that was new to the grid sector. DigitalCo put a lot of effort into understanding the grid sector in its meticulous detail, including its eclectic law landscape.

After the kickoff, efforts were directed toward mobilizing resources, establishing project formalities, and negotiating contract terms. GridCo officially signed the contract in May 2018, which included statements regarding GridCo's financial and human resource obligations for the course of the project.

As soon as formalities and project details were in place, DigitalCo engaged an agency to facilitate workshops for mapping processes, generating ideas, and identifying problems and needs of GridCo.

Four workshops were conducted and were viewed as a means to include GridCo in DigitalCo's thought process: "*The people who initiated the project had a lot of good ideas beforehand. So I think arranging those workshops was more to get the participants on board with those ideas, than necessarily getting the ideas out of them… But that's also an important process"* (Respondent 21, DigitalCo).

The workshops generated a broad list of requirements for the digital twin, including must-haves like "be flexible, available, and customer friendly" or "be advantageous in both daily operations and fault situations." By thinking through requirements, participants were simultaneously forced to ponder about a set of overarching goals pursued with a digital twin. Apart from generic goals, such as "maintaining continuous distribution of electricity to customers," "giving employees opportunities to work in new ways" or "gathering all relevant information in one system," participants settled on the following:

- Contribute to an increased task efficiency through analytical support and automation
- Automate decision support
- Contribute to an increased up-time (i.e., reduce number and consequences of power outages)
- Contribute to a faster reparation of faults in the grid
- Enable the simulation of grid changes before implementation

Another output from the workshops comprised a visual prototype of the digital twin. More specifically, it entailed a presentation of what the digital twin eventually could look like, with suggestions for its design and features based on workshop discussions.

It was also during this phase that GridCo shared a first set of test data with DigitalCo, containing fictitious data to reflect GridCo's grid network; the data represented the structure of the grid network, but not how it was laid out in reality, and was intended to provide a foundation for DigitalCo to start the digital twin development.

Phase 2: Experimentation and prototyping

Before the development of the Digital Twin could actually start, and as part of a second phase, GridCo conducted a thorough risk assessment concerning IT security and data sharing. This is of particular importance, because the Norwegian energy sector is subject to regulations of the "Norwegian Energy Act" and "The Regulation on Security and Preparedness in the Energy Supply". According to the Act, data about the grid network is regarded as sensitive power system information, and thus, cannot be shared with outsiders without further ado. Accordingly, GridCo had information security agreements signed, established a secure file transfer protocol (SFTP) solution for data extraction, and continuously evaluated risks. DigitalCo, on their hand, assigned designated cyber security resources to the project.

Once data and security measures were in place, the development started with DigitalGrid adding members from DigitalCo to their team. Specifically, two full time developers were assigned to the DigitalGrid team in Norway, in addition to a large team of developers from DigitalCo in India.

The developers at DigitalCo worked in sprints of two weeks and arranged monthly virtual sprint demonstrations for GridCo to attend and to get updates on the digital twin development. Every third month, when the sprint demonstrations were a bit larger in scope, the team met in person. The sprint demonstrations enabled DigitalCo to visualize the digital twin and show the development progress. This, in turn, generated discussions about the next steps in the development with the result that tasks were assigned to all parties, including GridCo, DigitalCo, and other project partners. The sprint approach was maintained during the entire second phase, with DigitalCo putting down extensive development efforts. A first version of the digital twin was launched in May 2019, and a second in December 2019.

The second phase was characterized by exploration, experimentation, and idea testing. DigitalCo developed proof of concepts (POCs) and added features to the digital twin on a continuous and ongoing basis. The main focus of the project during this phase was to develop features and tools for identifying and handling bottlenecks in the grid network. This involved implementing electrical calculations to identify voltage issues in the grid based on data from AMRs, as well as machine learning algorithms to suggest reconnections or changes in the grid network to accommodate these issues.

Because the development was placed under DigitalCo's supervision and on their premises, the data underlying the digital twin were not comprehensive. For example, the data were anonymized (ref. sensitive power system information), did not contain any customer information, and only represented approximately 3% of the network area in GridCo's concession. But despite these shortcomings, the first prototypical version of the digital twin relied on enough data to reflect the real grid network in the respective area. It was also continuously updated with new features.

Already, the next version, which still included anonymized grid network data for the same area, allowed for informational updates on an hourly basis, including hourly consumption data at an aggregated level, as well as hourly switch position data (i.e., data on the configuration of the grid network). In order to comply with the regulations of the Energy Act, the data had to be scrambled (i.e., identifiable properties were removed) and shared through a common information model (CIM) using a standardized XML format.

Phase 3: Specification and realization of added values

As DigitalCo continued to staff more and more people on the project during the third phase, not only did the development speed increase but also the need to interact with GridCo on a regular basis. As a result, GridCo was putting in more time as well.

While the four-week sprint approach was maintained from phase two, phase three had a more user-driven focus. Driven by fear to end up with a digital twin that had no utility, GridCo decided to take a more active role during this phase, ensuring that the digital twin would in fact accommodate their needs. Accordingly, GridCo engaged in creating specific use cases to guide the further development of the digital twin. The use cases represented specific needs GridCo identified as part of their daily operations and long-term planning of the grid, and were presented to the developers at DigitalCo as preferential focus areas of the continued development. DigitalCo agreed with the directions GridCo suggested, and linked features of the digital twin to the grid company's processes.

Later in the third phase, the digital twin was transferred to GridCo's premises and supervision, allowing GridCo to expand the scale and scope of data used for the digital twin without risking the exposure of sensitive power system information. For example, GridCo widened the scope of the structural data shared with the digital twin to represent their entire grid network area. Also, routines were established to increase the extraction speed of consumption and switch position data, moving from an hourly interval to real time.

Both, the type of data as well as the interval with which data were updated, allowed the third version of the digital twin to emerge, with the aspiration to further increase the amount of real time data from a variety of data sources. Housing the third version of the digital twin at GridCo also enabled them to test and use the digital twin and evaluate its ability to serve their needs more actively.

It was also during this phase that GridCo's management realized the strategic value of the digital twin in particular and the DigitalGrid project in general. As indicated in internal project documents, it became obvious that the DigitalGrid project was considered valuable in preparing GridCo for tomorrow's challenges in a profitable and efficient manner by initiating future-oriented initiatives in the grid, and by utilizing and sharing data more efficiently. The digital twin had turned into an essential part of GridCo's digital transformation effort.

The Digital Twin Today

The digital twin is available as an application, where users are presented with a map of the grid network area. The map shows all identifiable components, such as house branch lines, distribution cabinets, feeder cables, grid substations, cable lines, substation departures, substations, in their exact location. For each component, accompanying information, such as voltage level, type of cable, length of cable, electrical properties, alarms, and warnings are provided.

Predefined rules, based on grid sector standards, are applied in the graphical presentation of the grid network components. For instance, solid lines in the map represent underground power cables and stapled lines represent aerial power lines. Further, if the line has a grey color, no electricity flows through this power line (i.e., the power switch in the substation feeding this cable is turned to "off"). A component highlighted in yellow indicates that this component is reaching its loading capacity (i.e., 80% of nominal current), and a component highlighted in red indicates that this component is overloaded (i.e., over 100 % of nominal current).

Figure 4 includes some screenshots from the digital twin. Note, and in compliance with the Energy Act, these images do not reflect real data.

FIGURE 4. THE DIGITAL TWIN

The digital twin is built on an open information model, enabling GridCo to feed it with data from several sources. Currently, the digital twin consumes the following main data components:

- Grid network structural data: Data regarding the topology and setup of the grid network, drawn from the network information system (NIS). It includes data about a variety of features regarding all components in the grid network, from metering points to substations.
- Consumption data: Data regarding consumers' energy consumption, drawn from AMR readers.
- Switch position data: Data regarding the configuration of the grid network, showing from which substation and through which power lines the electricity flows (i.e., how the grid is connected), drawn from the distribution management system (DMS).

GridCo's hope is that a future digital twin will be able to consume more types of data, such as data stemming from other internal information systems and grid sensors, as well as data stemming from external sources, such as weather data. According to GridCo, "*everything that can be monitored in the grid in some way is very interesting*" (Respondent 1, GridCo). By increasing the amount and quality of data extracted from the physical grid that flows into the digital twin, the more powerful the digital twin will become as a tool for conducting simulations and providing support in decisions regarding the operations, maintenance, and development of the grid network.

Today, the digital twin holds features that have proven valuable for operating and maintaining the grid network in the short term, as well as for planning and developing the GridCo in the long term.

First, the digital twin provides a real-time picture, as well as a historical recollection, of the network with all its components. Ranging from larger substations to individual metering points in private households, GridCo is able to monitor the overall electricity flow, the grid's capacity, and the status of each component at any point in time, from now and back in time. This allows GridCo to identify bottlenecks in the grid network and make adjustments to the grid's configuration, for instance, by rerouting electricity from one substation to another and thus alleviating a specific area. As a result, GridCo can address grid issues more proactively and, hence, foresee power outages even before they occur. In case of faults, GridCo is also able to repair those more efficiently with the knowledge from the digital twin. This is important because climate change and the associated extreme weather situations have increased the complexity of fault situations, together with a grid infrastructure that is ageing and several grid components close to peaking in capacity.

Although existing information systems at the grid operation center were able to provide real-time insights of the network at a substation-level, the functionality of the digital twin is the first to provide insights of lower-level components in the grid network, as well as the ability to move backwards in time to get an adequate view of the grid network over time.

Second, the digital twin provides a powerful tool for simulation, both for daily operations, for instance by suggesting solutions to fix bottlenecks identified showing different scenarios, as well as for a more long-term perspective. As part of the EUs 2030 Climate Target Plan[9], for example, the Norwegian government has set a new objective of turning the entire Norwegian passenger ferry fleet electric by 2025. Because ferries return to dock every two hours on average and require electricity to recharge, GridCo is now, with the help of the digital twin, able to simulate how the set of ferries will not only affect the load and capacity of the grid but also the flow of electricity regarding other customers in the network. Based on the recommendations from the digital twin, GridCo can now make appropriate adjustments to re-configure the network before the electric ferries become reality. Hence, the digital twin enables GridCo to meet the new expectations regarding electrification and electricity consumption.

Third, and last, the digital twin has opened GridCo to envision new venues. Specifically, by installing additional sensor technology into the network and integrating these with the existing digital twin, GridCo is now better positioned to explore greater flexibility potentials. For instance, GridCo, together with DigitalCo, is currently experimenting with smart devices, such as smart water heaters, installed onto the traditional heater system with the permission of the owner. Given that a 10-minute shower requires a water heater to be running for at least two to three hours after the shower has already ended and given that most people take showers during the same time slot in the morning, causing a spike in consumption, the usage of smart water heaters open up new possibilities by turning water heaters off

[9] https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en

and on based on the overall load and capacity of the grid. As one DigitalCo respondent explained: "*The water heater is kind of like a thermal battery, and it's very easy to move. It doesn't matter for you or your household. As long as the water is hot when you wake up and get home from work. And it's really very easy to move the load without it bothering anyone*" (Respondent 20, DigitalCo).

TABLE 1. BENEFITS OF THE DIGITAL TWIN IN ACCOMMODATING GRID SECTOR CHALLENGES

Beneficial applications of the digital twin	**Accommodating...**
Providing real-time and historical insights	● Extreme weather conditions ● Ageing grid network components ● Overloaded grid network components
Running simulations	● Compliance with EU targets and Norwegian mandates ● New consumption patterns of increased electrification ● New production patterns
Exploiting new venues	● Overloaded grid network components ● Increased electrification ● New consumption and production patterns

Lessons Learned and Recommendations

Organizational Learning and Evolution

The DigitalGrid project spanned several organizations working together towards the same goal of developing a digital twin. The project evolved incrementally over time. GridCo was well aware that the project constituted an ongoing learning process, which was also one of the main reasons for them wanting to participate in the project. As one respondent noted: "*The digital knowledge in the company has evolved. And that was one of the motivational sources for doing this in the first place: to mature the organization*" (Respondent 8, GridCo).

By taking part in the project, GridCo was challenged to think differently, and an understanding of challenges and purposes evolved. What started out as a broad idea, was channeled by workshops with users in the first phase, and then narrowed down by prototyping an initial digital twin with concrete, yet limited, features in the second phase. IT security issues were tackled and viable solutions found for sharing data with the digital twin. The ensuing third phase was characterized by an even closer cooperation and increased levels of specificity in that GridCo was able to become more and more specific in expressing its needs and requirements, which DigitalCo accommodated. As one respondent from GridCo admitted, over time "*we probably have become a bit more 'demanding customer'. Because we have started to understand more, and started to become more specific*" (Respondent 8, GridCo).

In fact, challenges were viewed as important milestones of maturing: "*Through the project, we are challenged to think more thoroughly of what our problems are and what our needs are. They challenge* *us. The project challenges us. And that again results in competence building, and us paying a lot more attention to the market.*" (Respondent 7, GridCo). As learning matured, GridCo was able to more actively specify its needs and demands for the digital twin, which in turn helped the digital twin mature. Learning was acknowledged as an active ingredient in the project, and so was the communication among project members: "*The benefit is that I can sit here and tell you what I'm telling you. I would've never been able to tell you this if I hadn't been part of this project. And it's not just me, that goes for the entire project. Being part of the project has developed our knowledge and matured us as a company*" (Respondent 1, GridCo).

To think outside the box, you need competencies outside the box

The composition of competencies helped as well. GridCo's domain knowledge about electric grid networks complemented DigitalCo's knowledge about process technology, data, modelling, and simulation that DigitalCo had accumulated over time and with digital twin designs in other industries. For GridCo, it was valuable learning to see what DigitalCo had accomplished and how digital twins were successfully implemented and applied in other industries. Throughout the project, GridCo emphasized how the grid sector newcomer DigitalCo challenged GridCo to think differently, introduced new technology, and engaged with actors unfamiliar to GridCo. This, in turn, enabled GridCo to gain new insights from their own sector and ways of working.

Unprecedented use cases for the digital twin will lead to an evolution of the physical counterpart

Although the goal of digital transformation had been present the entire time, it was not until later that GridCo realized the full potential of the digital twin, and how it would impact GridCo's operational and grid development practices in its entirety. Both, GridCo and DigitalCo, were well aware that simply creating a digital clone of a physical product equated to not utilizing the project in its fullest potential. They understood that when transitioning into the digital realm, organizations have to sit down and contemplate which characteristics are possible in the digital realm that are *in addition* to those in the physical realm. In other words, physical entities that are translated into the digital realm gain attributes**.** For example, while the physical grid provides readings about electricity consumption, the digital grid, because it is interlinked and exchanges data, is able to conduct simulations on predicted changes in consumption patterns. Likewise, one can think about a chair. In order to mirror the physical side of a chair, one can easily envision a system that captures data about the chair's size and form, its shape and fabric. But a truly digital chair might also store when it was created, by whom, and how often it was sat on based upon a sensor embedded in its cushion. In that sense, the digital twin is not really a twin but an enhanced twin. It has more characteristics than its physical counterpart and can lead to new business opportunities if it is fully utilized. For instance, by integrating sensor technology from electric vehicle chargers in customers' garages, solar panels on their roofs, and other smart devices across the grid network. Therefore, it is incumbent to evaluate what those additional characteristics are, as mentioned by the organization: "*[We need to] study our processes: 'Where do we find that the digital twin can be* *the most useful or valuable?' And to do that we first need to understand what the digital twin is,* and *then we need to look more closely at our processes: 'Where can we get something out of this digital twin?'*" (Respondent 6, GridCo).

Instruments in Co-Creative Projects

Particularly during the initial idea-generating workshops and the subsequent sprint demonstrations, DigitalCo relied on sparring with and feedback from GridCo on a continuous and ongoing basis. Both parties highlighted that this design approach was a vital ingredient in the success of the digital twin. For GridCo, this user-centered design was important to ensure that it was not just acquiring "yet another software" and that the digital twin would serve its needs and accommodate its problems. For DigitalCo, a user-centered design was important to ensure that it developed a digital twin that is of value and utility for users. As DigitalCo put it: "*It's really co-creation. The idea is to make the software together. That's the whole concept. To sit in the office and think you can come up with something genius without actually involving those who actually have a need, is hopeless*" (Respondent 20, DigitalCo). In sum, both designers and users should be in it for the knowledge, not for the development.

Let stakeholders live through challenges and solutions based on adaptive storytelling

Armed with a background in digital twin development, but no domain-level knowledge in the grid sector, DigitalCo exploited various approaches to bridge the gap while getting GridCo involved. For example, DigitalCo utilized the idea of *storytelling*. The interview respondents used the Norwegian term "*historiefortelling*"; which can best be understood as something in between fairytales and scenario portrays. In lack of a better translation to English, we use the term "storytelling" here. Specifically, DigitalCo engaged GridCo in stories of grid sector challenges, as a form of role play, to contemplate different scenarios, and by doing so, was able to demonstrate, and often resolve, how a digital twin could possibly accommodate any or all of these challenges. Scenarios were mostly drawn from GridCo as a company and the grid sector as an industry, along with standards, rules, and regulations that apply.

GridCo was very appreciative of how DigitalCo was able to illustrate the consequences and severity of grid sector challenges with the help of scenarios (the respondents even mentioned the term "horror-scenarios") and eventually a prototype. For the first time, GridCo was able to envision a solution that was promising in addressing many of its challenges. As DigitalCo witnessed: "*It's all about telling a story about flexibility, problems, and solutions. And then use our own tools to illustrate that it is actually possible to solve. Because people don't think it's possible, but it really is*" (Respondent 20, DigitalCo). The result of storytelling was not only a better understanding, but first and foremost GridCo's buy-in. By involving GridCo in storytelling, DigitalCo was able to learn about grid requirements whilst creating a productive working relationship.

Foster detailed analysis and vibrant discourses, especially in the requirement phase

A close collaboration also requires a commitment to communicate. Creating a digital twin is not only about translating a physical entity; it is first and foremost about conceptualizing it. And this conceptualization requires exchange and discourse among all players and truly understanding the properties of the digital conceptualization. As stated by a DigitalCo respondent, *"you really need to talk through all the details… and my understanding and respect for these things has just increased during the project. Because I can be quite a pragmatic, kind of like 'Ok, now we have understood it, let's just get going!' But you can't just do that. And these differences, they're not just small nuances… they can be big differences. So you need to talk your way through the processes*" (Respondent 21, DigitalCo). For the digital twin project to succeed, the requirement phase received a lot, if not the most, attention.

Encourage continuous stakeholder feedback along the road, not at the finish line

Apart from methodologies and frameworks, DigitalCo also adjusted its coding approach. As versions of the digital twin were illustrated during sprint demonstrations, GridCo had the opportunity to provide feedback to influence the content and graphical interface of the twin. Moreover, as different versions were released (version 1 and 2 in 2019, version 3 in 2020), GridCo had the opportunity to test-drive the digital twin solution themselves, and report back to DigitalCo on issues, like the ease of using the digital twin. DigitalCo learned early on that GridCo needed an intuitive design and thus relied on regular feedback from GridCo to ensure that the digital twin and its features follow with familiar tools and logical graphical interfaces. Such involvement from GridCo also required a management that allows for experimentation, which was very much the case for GridCo. One GridCo respondent explained: "*I believe management has faith in us. I am allowed to test and fail a bit. So I feel there is a proactive mentality in GridCo now, allowing us to put some speed to things. And that is a strength we need to get where we want to be. So, a culture where 'we can do this' and we are to be proactive, take some risks and see where it will take us. We are allowed to fail, and 'fail fast', within certain limits of course*" (Respondent 1, GridCo).

Effective Data Governance

While the digital twin project was born out of a rather serendipitous encounter between an energy executive and an IT executive, both parties were convinced of its value early on. GridCo, as well as DigitalCo, realized that even a failed project would carry a silver lining for future IT projects, as the following quotes demonstrates: "*I believe that the great benefit of being part of this project is the learning and experience we get to take part in. Both regarding data security, and data exchange between internal and external systems*" (Respondent 3, GridCo).

GridCo understood that it had to face data governance and associated security issues—if not as part of the project with DigitalCo, but then with others down the line. In that sense, GridCo's risk was calculated. Nevertheless, and as GridCo experienced early on, data security was a tremendous, and almost impenetrable, barrier for getting the project off the ground. It certainly slowed down the initial phase considerably.

Create clear guidelines for management and exchange of sensitive twin data

Because of the sensitivity of the grid network data, one main challenge entailed the question of how GridCo could possibly share grid network data with DigitalCo since those were, and still are, classified as power sensitive. Moreover, GridCo lacked clear guidelines from management on data exchanges in the beginning of the project, and DigitalCo did not provide adequate documentation on data storage and treatment. However, as a GridCo respondent explained: "*the DigitalGrid project has contributed to opening our eyes to the complexity of IT security*" (Respondent 6, GridCo). Working together with DigitalCo, GridCo managed to eventually find viable solutions for data exchanges. The knowledge and experience gained with regards to IT security and data governance issues are, according to GridCo, one of the greatest benefits of being part of the DigitalGrid project, which they believe would be valuable to them in other future settings as well.

Integrate external stakeholders in your organizational data map

It truly became apparent that a digital twin can be a trigger to re-think internal data structures. Even if not implemented as a digital twin, having discussions about what data would be necessary to create one can be extremely fruitful. Companies will have to re-think their data flows, and particularly their data silos that exist within the company, and by doing so, might discover that even the simplest form of a digital twin might not be feasible. But even if it is, organizations might notice that some of the data is dependent upon the successful interchange with other providers. In that case, including those providers as part of their organizational data map might be a good idea.

Expand and contribute to industry-wide data standards

What started off with conceptualizing a digital twin soon required a rethinking of the internal data structures and ended up with contributing to an industry-wide standardization effort. For example, GridCo's digital twin required the use of the entire grid network in a digital format, along with all grid components and their properties. For that, however, the map layout needed to be standardized. As a result, the grid network structure and configuration were revised according to grid sector standards. As GridCo explained, the digital twin is built on "*a standardized information model where voltage is voltage, and electricity is electricity—so that you can compare apples with apples and bananas with bananas*" (Respondent 1, GridCo). And "*The processes are a bit different in each grid company… That's what's fascinating about Norway; there are around 100 grid companies, and they're all different. Even though everything physical in the bottom is exactly the same, everything is different* (Respondent 21, DigitalCo).

Rethinking standards and data structures was soon followed by the opportunity of re-thinking how an "energy system" could be conceptualized from an industry perspective. In fact, more than 25 year ago, 61 Norwegian grid companies, among them GridCo, founded REN (Rasjonell Elektrisk Nettvirksomhet/Rational Electric Grid operations), an industry-wide knowledge-center for the grid sector industry. As part of the digital twin development, it turned out that the guidelines and standard methods put forth by REN mostly do not cover the topic of “data”. Hence, the digital twin project was the very first to make use of the “common information model” (CIM) established by DIGIN (DIGitaliseringsINitiativ for energibransjen / DIGitalization INitiative for the energy sector). DIGIN now represents a market leading collaboration between GridCo and other grid companies in Norway to ease data exchanges between such organizations.

Along the same lines, the development of the digital twin triggered the birth of a new project amongst the three grid companies involved; a project set out to develop an example-driven guide for managing IT security and interpreting regulations such as the “Norwegian Energy Act”, “The Regulation on Security and Preparedness in the Energy Supply”, and GDPR. The project’s motivation is to establish a guide that will serve as a grid sector standard and help other grid companies with similar data-related issues, as the DigitalGrid project faced, in the future. In fact, the regulators (NVE: The Norwegian Water Resources and Energy Directorate) are already on board to verify the guide.

Conclusion

As the DigitalGrid case has shown, a digital twin development is not solely about translating the physical into the digital—rather, it is about the mindset changes that the development of the digital twin would bring about. Building the actual digital twin to increase grid performance is important—but even more important, one could argue, is to use it as a conceptualizing vehicle for development and self-reflection. Unbeknownst at the beginning, the reflections and later implementations of the digital twin turned into key ingredients in GridCo’s overarching strategy and digital transformation. In fact, it laid the groundwork for what ended up paving the way for an industry-wide standard.

Data Collection

We relied on three sources of data over the course of three phases of the DigitalGrid project: interviews, observations, and archival documents, where interviews served as the main data source. Table 2 illustrates the different data sources.

TABLE 2. DATA SOURCES

	2018 (Phase 1)	2019 (Phase 2)	2020 (Phase 3)
Interviews	7	11	9
Observations	● One author spending 1-3 days per week with GridCo (September 2018 - July 2020) ● Participation in meetings, seminars, workshops ● Informal conversations with project members ● Demonstration of the digital twin versions ● Participation in sprint demonstrations ● Field notes		
Documents	● Formal project documentation ● Internal project documentation (GridCo) ● Strategic documents (GridCo) ● Other relevant documents		

We conducted 27 semi-structured interviews with 22 respondents during the three phases. In the first two phases (2018 and 2019), interviews were conducted with respondents in a variety of positions and departments in GridCo, some of whom were more directly involved in the DigitalGrid project than others. In addition, interviews non-related to the DigitalGrid project were conducted with 28 respondents from GridCo during this period, which served as a foundation for gaining a rich understanding of GridCo and the Norwegian grid sector. In the third phase (2020), we pointed our interviews more directly towards the DigitalGrid project, supplementing interviews with respondents from GridCo with respondents from the developing company, DigitalCo. In total, nine interviews were conducted in the third phase; seven GridCo respondents and two DigitalCo respondents. Each interview lasted between 40 and 90 minutes.