Disclosing from Disorder: Exploring the Interrelationship between the Accounting Craft and "Big Data"

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To Cathrine and Liam.

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It probably goes without saying that this body of work could not possibly be accredited only to its author. Like any object in the social world, there is also a network tied to this dissertation, of which I only constitutes one small node.

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Introductory Chapter

I. Interrelating Big Data and Accounting for Disclosure

This dissertation aims to investigate the interrelationship between accounting and the deluge of data, often referred to as "big data" (Kitchin, 2014). The hype surrounding big data is still real. As organizations and societies become increasingly computer mediated (Zuboff, 2013), data has reached unprecedented volumes, travels at high velocity, comes in a variety of forms, and is largely unstructured (Grover et al., 2018). Big data enthusiasts argue that these developments offer ample opportunities to reduce costs, make faster and better decisions, and develop new products and services (Anderson et al., 2008; Davenport et al., 2012). This view suggests that if big data is harnessed, there is inherent potential for the *disclosure* of knowledge that was previously beyond the reach of organizations (Goes, 2014; McAfee & Brynjolfsson, 2012).

Disclosure from big data should not be understood as purely an act of revealing or referencing through measurement something that is already there. Rather, the view adopted in this dissertation is that "disclosure" is about *making objects appear so as to generate alternatives for organizational interventions*. In other words, objects such as consumers' behavioral patterns (Zuboff, 2019) or operational performance measures (Qin, 2014) can be made up (Hacking, 1986; Young, 2006) from the deluge of data and, thereby, present "a plane of possibilities that did not exist beforehand" (Kornberger et al., 2017, p. 91; Lury & Marres, 2015) on which interventional alternatives can be based.

This may be one reason why researchers have shown increasing interest in big data and its relationship with accounting (Bhimani & Willcocks, 2014; Quattrone, 2016; Kornberger et al., 2017; Knudsen, 2020). After all, the notion that accounting discloses objects of various kinds through the laborious *crafting* of "an accounting eye" that enables "new means for intervening in the organization" (Hopwood, 1992, p. 134) is widely accepted. As such, accounting disclosure is not simply the revealing of some underlying economic truth that, when made visible, for example, influences firms' cost of capital (Lambert et al., 2007). Instead, it is a craft with the "capacity […] to create an openness wherein things and people can show up" (Spinosa et al., 1999, p. 190), allowing a multitude of objects to become visible, calculable, manageable, and potentially connected to aspirations of innovation and change (Miller, 1992; Revellino & Mouritsen, 2015).

Some researchers have probed into the ways in which accounting in the big-data context is mobilized for disclosure. For example, Kornberger et al. (2017) argue that accounting and big data are both elements in infrastructures that, *inter alia,* enable the "disclosing" of new objects (p. 85). Specifically, they show how "trust," an ambiguous interpersonal attribution, becomes disclosed and manageable through an "ecology of devices" (p. 83) and practices connecting accounting in the form of evaluations, behavioral (big) data, and technological artifacts. Similarly, Quattrone (2016) argues that accounting and big data are interchangeably involved in practices of disclosing new objects (e.g., aspects related to employees' private lives). Although the objects that are disclosed through big data—that is, new accounting numbers—should always be treated as flawed and in need of supplementary human judgement, they still represent "a dream of full control [where] the realm of the measurable is expanded and could theoretically be extended to our entire lives" (Quattrone, 2016, p. 3). These two studies collectively point to the idea that the intertwining of the accounting craft and big data enables the appearance of new objects that can be used in the management and control of organizations.

The fact that the accounting craft can be performed in conjunction with information technology to disclose objects is not new (Andon, Baxter, & Chua, 2003; Dechow & Mouritsen, 2005; Quattrone & Hopper, 2005). However, contemporary organizations see a need to develop their technological architectures in order to harness the apparent potential for disclosure in big data. For example, enterprise-resource planning (ERP) systems and their underpinning architecture have a tendency to put tight restrictions on the types of data that are allowed to be stored. Hence, big data and ERP systems are by some considered and "inept couple" (Elragal, 2014, p. 242).

Disclosure from big data seems to require architectures and data structures that explicitly allow for the quick connection of vast amounts of miscellaneous datapoints to address a range of shifting problems. Architectures must be purposefully designed to break free from the "inertia of the installed base" (Star & Ruhleder, 1996, p. 5; Monteiro & Hanseth, 1996) and embrace "disorder" (Constantiou & Kallinikos, 2015a; Weinberger, 2007). In fact, the disorder of technological architectures is argued to allow for the deluge of data to be (quickly) collected, connected, and presented. Constantiou and Kallinikos (2015a) elaborate on why contemporary organizations need to consider the makeup of their architectures if they are to tap into the potential of big data:

> Obviously, in the current context dominated by computer technologies, even the most haphazard data collection needs an underlying technical infrastructure of data fields, data structures and architectures through which data is captured and stored. However, it makes

> a difference, and a rather important one, what types of data such a system admits. By the same token, it makes a great deal of difference whether data is gathered through a carefully laid out cognitive (semantic) architecture or, by contrast, is captured and stored without such a plan and on the assumption that it may be variously used a posteriori. This is a fundamental difference that Weinberger (2007) captures by the terms "sorting in the way in" vs "sorting in the way out". "Sorting in the way in" implies a clear structure and information architecture of data collection whereby data is ordered and its location fixed once-and-for-all at the moment it enters a system or data infrastructure. "Sorting in the way out" entails the capacity to meaningfully categorize and assemble unstructured and miscellaneous data and information that have been gathered or generated on loose premises. (Constantiou & Kallinikos, 2015a, p. 49)

Information systems can be—and increasingly are—designed without ambitions of an a priori ordering of data. In fact, in the Petabyte Age (Anderson et al., 2008), strong proponents argue that these systems are the only viable way forward. Without systems geared towards "sorting in the way out," (Constantiou & Kallinikos, 2015a, p. 49, Weinberger, 2007, p. 84) new objects become difficult to disclose and the potential of big data remains left untapped.

In contemporary organizations, accounting is increasingly crafted in relation to disordered systems (Kornberger et al., 2017; Quattrone, 2016), and implicated in efforts to disclose objects that were previously outside the scope of "the accounting eye" and make them manageable (Hopwood, 1992, p. 134). Accounting is needed for big data to be transformed into something "understandable and actionable" (Ronzani & Gatzweiler, 2021, p. 1). It plays an integral role in the "categoriz[ation] and assembl[y of] unstructured and miscellaneous data" (Constantiou & Kallinikos, 2015a, p. 49), and imposes some order on the disorder. It makes the data disclose what is "hidden" within and generates intervention alternatives.

As outlined above, researchers have begun to investigate how accounting is crafted to disclose in environments characterized by a deluge of data and disordered systems. These studies offer important contributions and set up an agenda for further research on the interrelationship between big data and accounting (see, e.g., Kornberger et al., 2017). However, empirical field studies remain scarce, leaving us with arm's-length claims and theories about how the accounting craft and big data intertwine to allow for disclosure in contemporary organizations. Given that expressions of technologies, like accounting and big data, deeply influence and are influenced by their context (Hopwood, 1987), empirical studies of the particular objects that are disclosed and the implications of their disclosure are needed to enrich our understanding of the interrelationship between accounting and big data. Hence, this dissertation's overarching research aim is to understand *how the accounting craft and big data intertwine in the disclosure of new objects, and the implications of this interrelationship.*

To address this aim, I conducted a longitudinal field study of digitalization in EnergyCo, a pseudonym for a multinational company operating mainly in the petroleum industry. Through the launch of a digital strategy, EnergyCo made substantial investments in establishing a disordered system for disclosing new things through big data. In particular, I investigate the connections between this disordered system and digitalization projects in the organization's maintenance operations, and the intertwining of the crafting of accounting representations with big data in order to improve maintenance.

The remainder of the introductory chapter is structured as follows. In the next section, I elaborate on my research methodology and present the empirical case. In the subsequent section, I present the three articles contained in this dissertation. The final section brings together the contributions from the articles and discusses them in relation to the overarching research aim.

II. Research Methodology

A. Ontological and Epistemological Stance

This dissertation adopts a view of accounting as a dynamic and organizational *craft* (Hopwood, 1987, 1992) and, thereby, acknowledges accounting as deeply interwoven into situated practices. The conceptualization of accounting as a craft puts the emphasis on the laborious work that goes into the production of accounting numbers. Accounting, as such, is a practice and not just an object. This perspective does not view any form of accounting as superior in the "revelation of […] economic truths" (Hopwood, 1992, p. 142) and, thus, as stable across time and space. As such, accounting has no "essence" (Miller, 1998, p. 619). Instead, it continuously shifts and becomes what it was not (Hopwood, 1987). Accounting is simultaneously shaped by and shapes the context in which it operates—a context that frequently shifts due to fads, politics, and societal developments. However, as accounting is seemingly objective and neutral (Robson, 1992), it is easily transformed into a tool that serves an agenda. Even though accounting numbers have no essence, they tend to be trusted (Porter, 1995) and are frequently wielded in the name of achieving objectives.

The assumption that accounting is bound to context also suggests that it can never be "complete" or provide a full-resolution image of reality. Something will always be absent. However, deliberate choices are made about what is to be included in the "incomplete" (Quattrone, 2009) representation. This does not imply that malicious intentions are always behind this selection. At the same time, it should never simply be assumed that accounting always represents reality. In fact, accounting is always a value statement. Hence, viewing it as a dynamic phenomenon keeps us from adopting descriptions that are only representational. The observed expression of accounting may be, for instance, a balance sheet, a profit and loss statement, or a balanced scorecard, but the process that goes into producing and upholding that representation is just as important. In other words, adopting a dynamic view of accounting allows us to go beyond investigating accounting as a discrete entity towards an understanding of the relational ecologies, including technologies like big data, to which accounting is always connected.

A dynamic and organizational view of the accounting craft rests on a predominantly critical ontological assumption. The critical perspective could be easily interchanged with the interpretive perspective. However, there are some foundational differences between the two. Interpretivism posits that using principles from the natural sciences to understand the social is futile. Rather than presuming a fixed and objective world, the world is assumed to be emergent, subjectively formed by the people who inhabit it, and "objectified" through human interaction. The world is constructed, and meanings and norms are established through social interactions among humans (Berger & Luckmann, 1966). These meanings and norms make up (Hacking, 1986) social reality, and some of them "become institutionalized, taken for granted, and used to typify (structure) experiences" (Chua, 1986, p. 614).

A surficial interpretation of the critical perspective would render it interchangeable with the interpretive perspective, in that the former also claims that criteria for judging theories are temporal and context-bound (Chua, 1986). However, the critical perspective *criticizes* the interpretive stance for failing to evaluate and assess the consequences of socially constructed categories. These social constructs are the result of power struggles in society, where the "reality" and "facts" of the powerful are reified at the expense of the less powerful. Therefore, current societal arrangements and categories should not be taken for granted but critically investigated through methods like historical genealogy (see, e.g., Foucault, 1977). As such, the critical perspective is set apart from the interpretive mainly because it claims power struggles always undergird socially constructed reality.

This dissertation primarily subscribes to a critical perspective, as it never assumes that accounting or information technology are neutral. Technologies emerge to address social issues and have no objective essence existing in an objective plane. They attach themselves to multiple goals and ambitions of diverse groups of actors. This stance, however, should not be viewed as a discrediting of other perspectives or a critique of their claims. Instead, it is about acknowledging the political processes and (more or less) latent power struggles involved in the construction of objects. We often fall into the trap of thinking about systems and objects as reflections of some underlying "best practice" for addressing certain organizational and societal objectives, especially when they seem to successfully and efficiently address such issues. This dissertation, however, aims to open up the "black boxes" (Latour, 1987) that these systems and objects quickly become enclosed in, and critically assess the effects they have on people, organizations, and perhaps even society.

The ontological assumption adopted in this dissertation—the assumption that social reality is constructed and objectified through human interaction—subsequently shapes my views on how to attain knowledge about this reality. That is, if social reality is assumed to be constructed and continuously emerging, the epistemic tools used to attain knowledge about that reality must be adjusted in accordance with this perspective. They must be appropriate for making sense of the subject and its intentions and actions, the interactions between subjects, the objectified and temporary structures in which actors are embedded, and the interplay among all of these elements. The knowledge that is produced through the deployment of such epistemic tools must have logical consistency, emphasize subjective interpretations by seeking the meaning of an action to an actor, and be understandable and acceptable by actors as an adequate explanation of their intentions (Chua, 1986; Schutz, 1962). Methodological approaches and methods that emphasize "observation, awareness of linguistic ques, and a careful attention to detail" (Chua, 1986, p. 614) are well suited for understanding the qualities of human interaction. In line with this argument, a case-study methodology, including methods like ethnography, semi-structured interviews, shadowing, and document analysis, seems appropriate for producing "thick" descriptions (Lukka & Modell, 2010, p. 463) of the social reality and subsequent knowledge about that continuously shifting reality.

Hence, in order to explore the relations between the accounting craft and big data, I conducted a case study. The methodology and methods that are frequently adopted by researchers utilizing case studies provide ample opportunities to unearth how technologies like accounting and big data operate in context.

B. The Qualitative Case Study

The methodology selected to address this dissertation's research ambition—the qualitative case study—follows from the dissertation's ontological and epistemological stance. A case study grounded in a qualitative methodology acknowledges reality as "emergent, subjective, and [socially] constructed" (Ahrens & Chapman, 2006, p. 822) and, consequently, encourages an approach to research that includes a:

> [F]ocus on meaning, the use of analytic induction, maintaining a close proximity to data, an emphasis on ordinary behavior, and attempts to link agency to structure through accounts based on the study of events (routine or otherwise) over time. (Van Maanen, 1998, pp. 10-11)

The methods used to obtain knowledge about an assumed socially constructed world can vary. That is, studies adopting a qualitative methodology do not have to mobilize interviews, observations, and document analysis, even though these methods are the most widely used. A qualitative methodology also invites the use of quantitative methods (e.g., surveys) that align with the study's overarching approach and focus.

However, like the methodology, the methods should be selected in relation to the "theory […] to which it is intended to speak" (Ahrens & Chapman, 2006, p. 822). As such, methodology, methods, existing theory, and assumptions (i.e., tentative hypotheses) should all be intertwined in a "process of theorizing" (Baxter & Chua, 1998, p. 79) in which empirical data are connected and reconnected to research questions until the study is positioned to make a contribution to the literature.

In relation to the qualitative case-study methodology and overarching research aim of this dissertation, my data-collection process relied on the use of semi-structured interviews, observations, and document analysis to obtain knowledge about the relations between accounting and big data. However, before describing the data-collection process and analysis, I present the case organization.

C. Case Organization: EnergyCo

The empirical material on which this dissertation is based originates from a longitudinal case study of digitalization in EnergyCo (a pseudonym), a multinational energy company mainly operating in the petroleum industry. EnergyCo is a monolith in Norwegian industry, with more than 21,000 employees and operations in 36 countries. In 2017, EnergyCo launched a digital strategy with the aim of supporting the company's overarching strategy, making it a suitable case in relation to this dissertation's research aim.

The EnergyCo case is particularly interesting owing to the company's commitment to the adoption of big data. First, it invested heavily in reforming its "data infrastructure" (Constantiou & Kallinikos, 2015a, p. 49) by developing a cloud-based data platform named OMNIA. Its purpose was to enable the collection, storage, and retrieval of all available data from the organization's value chain (see Figure 1). In other words, EnergyCo invested in a disordered system geared towards "sorting in the way out" (Constantiou & Kallinikos, 2015a, p. 49, Weinberger, 2007, p. 84) and tapping into the potential of big data. In addition, digital tools were developed to achieve a multitude of objectives, such as increased safety, more efficient operations, and a reduced carbon footprint.

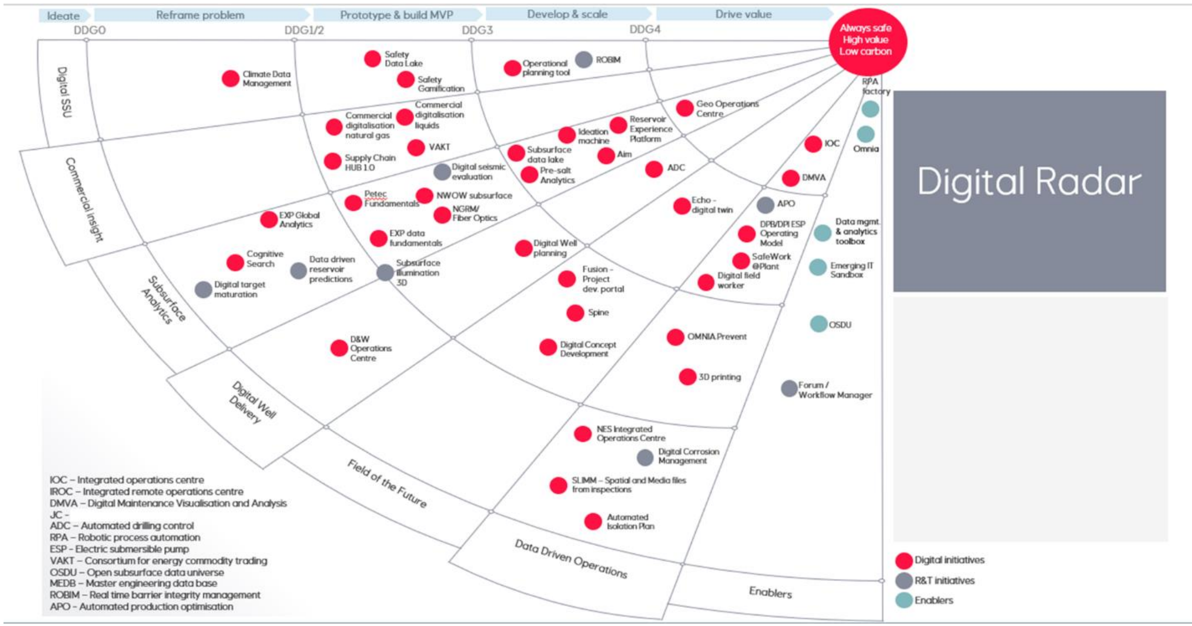

Figure 1 *EnergyCo's digital roadmap tracking the development of the entire portfolio of digitalization projects Note the dots for OMNIA, DMVA, and IOC, which are of particular interest to this dissertation.*

As depicted in Figure 1, EnergyCo's digitalization strategy cut across the entire spectrum of organizational activities. To focus the investigation, I followed the recommendations of informants and focused my attention on the maintenance operations. Two of the three most promising projects in the portfolio—the Digital Maintenance Visualisation and Analysis (DMVA) project and the Integrated Operations Centre (IOC)—were closely connected to the maintenance operations. Although other projects could also provide valuable insights relevant to this dissertation's research aim, the digitalization of maintenance work is a paradigmatic example of such initiatives (Jardine et al., 2006; Jonsson et al., 2018) and, as such, a sensible selection. In the maintenance-related digitalization projects, big data from OMNIA were combined and re-combined into representations aimed at improving operations. In other words, actors in the maintenance process tried to make big data "understandable and actionable" (Ronzani & Gatzweiler, 2021, p. 1) by producing accounting representations.

D. Data Collection and Analysis

Access to the case organization was established through the initiation of a research project between the author's institution and EnergyCo. During the project's initiation meeting, EnergyCo's maintenance operations were identified as a potentially interesting area for studying the relationship between accounting and big data.

The data was collected using various methods, including semi-structured interviews, observations, and internal and external documents related to EnergyCo. The predominant mode of data collection was semi-structured interviews (Qu & Dumay, 2011) conducted between March 2019 and September 2021 (see Table 2 in the Appendix). The interviews were conducted in three separate but interlinked rounds. The first round was exploratory in nature. Hence, the scope of the interview(ee)s was broad and included representatives from the company's Finance and Control department, external consultants, union representatives, and operative personnel. As the interviews were conducted, the "snowball effect" (Noy, 2008, p. 328) eventually led me to the DMVA project within EnergyCo's maintenance operations. This project was involved in turning (big) data from OMNIA into accounting representations that were to be used in improvement work. As such, it offered a suitable setting for an empirical deep dive.

In the second interview round, I was able to join the DMVA project on a full-time basis for three consecutive weeks. During this period, I observed and interacted with people involved in the project, and conducted a total of sixteen interviews. The fieldwork allowed me to access a number of internal documents through my EnergyCo computer that would have been difficult to access from the outside. I noted my reflections on informal interactions, observations, and internal documents in a fieldwork journal, which I supplemented with the interview material. The latter provided rich data that I referred to and drew from during the data analysis. The second round concluded with a presentation of my findings to a group of employees involved in the DMVA project, which served a dual purpose of "giving something back" to the case organization and validating my findings.

The third round of interviews was more haphazard in nature. At this stage of the research project, I was deep into multiple processes of theorizing about the empirical material, and frequently found it necessary to send emails or make calls to contacts in EnergyCo in order to gather additional information on certain issues. This process resulted in sixteen additional interviews of, for instance, operational personnel, engineers, and data analysts of various kinds and ranks. Due to the outbreak of the COVID-19 pandemic, most of these interviews were conducted via Zoom or Microsoft Teams, which reduced my ability to pick up on important informative cues, like body language, tone of voice, and informal conversations after the completion of the formal interview. However, it simultaneously mitigated the challenges associated with setting up and conducting interviews, thereby arguably contributing to the generation of a larger dataset than if I had not relied on these technologies.

Overlapping most of the data-collection process were multiple distinct but interwoven analytical processes in which the data from the interviews, observations, and documents was used for theorizing by recursively jumping between empirical material and theoretical conceptualizations (Baxter & Chua, 1998; Langley, 1999; Locke & Golden-Biddle, 1997). This process sensitized my co-authors and me to potentially interesting theoretical contributions to the literature over time (Ahrens & Chapman, 2006). We paid close attention to the formulation of our research questions and interview protocols, which were initially framed by the theoretical concepts of digitalization, big data, and management control, but we remained open to their gradual revision. Over the course of the research project, the dataset was used for theorizing in multiple ways, resulting in the three individual research articles that make up this dissertation. As such, my co-authors and I demonstrate how vast datasets can contain several plausible interpretations (boyd & Crawford, 2012) that can all contribute in unique ways to theory. More details on the specific data-collection and analysis processes for each individual article can be found in their distinct research-method sections.

III. Introduction of Articles

In this section, I present the three articles contained in this dissertation and link their contributions to the dissertation's overarching research aim. A short note is necessary in relation to the articles and their primary audiences. Although this dissertation investigates the relations between the accounting craft and big data, Article 3 is aimed primarily at an information systems (IS) audience. Rather than investigating the crafting of accounting for disclosure in a big data environment, it focuses on the outcomes of this interrelationship. In this capacity, its findings and contributions are still relevant for addressing the overarching research aim. As such, this section is structured to delineate between the articles targeted primarily at an accounting audience and Article 3. First, Article 1 is presented, as it aims to elaborate on the relationship between the accounting craft and the discourse connected to big data. Second, I present Article 2, which was the article developed last. It investigates what goes on "under the hood" of accounting inscriptions in contemporary organizations and how they are part of complex interrelated systems, including elements like big data, that are constructed to disclose objects. Finally, Article 3 is presented. This article shows how the interrelationship between accounting and big data can produce unintended consequences.

A. *Article 1—The Dream of Big Data: The Role of Accounting in the Performativity of New Technology*

The first article presented in this dissertation investigates the relationship between big data and accounting by analyzing efforts to mobilize big data and visualization technologies to "optimize" the maintenance processes in EnergyCo. Thus, the article aims to contribute to the growing body of research on the relationship between the two technologies (Appelbaum et al., 2017; Arnaboldi et al., 2017; Quattrone, 2016; Ronzani & Gatzweiler, 2021; Vasarhelyi et al., 2015; Warren et al., 2015).

To understand the relationship between big data and accounting, the article first makes an effort to disentangle the two concepts in order to compare and contrast them. This exercise is purely theoretical, and the aim is not to define the socio-technical properties of either big data or accounting. Rather, it is to delineate certain theoretical properties from the literature related to the discourse surrounding big data and, in turn, use those findings for a discussion about how these properties are compatible with the objective of accounting systems theoretically deduced thus far—that is, providing relevant information to a preconceived user group (Johnson & Kaplan, 1987; Power, 2010; Young, 2006).

Through a review of the literature on big data from multiple academic fields, we conceptualize big data as closely linked to a mythological proposition (Meyer & Rowan, 1977) about the value of large and varied datasets, and their potential to provide solutions across time and space in the face of an inherently unknowable future (Schwarzkopf, 2020). The proposition suggests that by collecting and storing all data, answers can inductively emerge or be disclosed from the empirical world without the need for specific queries up front (Kitchin, 2014). As such, data should valued for its own sake, as it can become "useful at a later point" (Constantiou & Kallinikos, 2015a, p. 13). This proposition produces what we label as a dream about management that is both objective and adaptive—a managerial style we call the *big data dream of scientific management 2.0*. It is objective because (big) data is frequently conflated with "facts," "evidence," "information," and "knowledge" in everyday language (Rosenberg, 2013) and, hence, connected to the rigor of science (Chua, 2019). It is adaptive because it refuses to subdue to notions from existing theory or preconceived categories in its recommendations (Alaimo & Kallinikos, 2021). Instead, the analysis of big data should disclose the "right" response to any emerging managerial problem.

The big data dream of scientific management 2.0 presents a challenge for accounting through its conception of what constitutes relevant information and who the users of information are. According to the dream, relevance should not be imbued on the data but rather emerge inductively. However, traditional accounting concepts and practices seem to be somewhat resilient even when faced with the opportunities new technologies provide (Arnaboldi et al., 2017; Salijeni et al., 2021). In other words, even if accounting objectives like "relevance" and "preconceived user groups" are at odds with the main proposition of the dream of scientific management 2.0, they are powerful notions that human actors draw on to interpret and interact with big and disordered (Weinberger, 2007) datasets. The performativity of the big data dream, therefore, may be intertwined with accounting, as the latter is needed to make disordered big data manageable. Hence, we ask the following research questions:

How is the performativity of Big data influencing or influenced by accounting?

Through our case study of the digitalization of EnergyCo's maintenance operations, we investigate the role of accounting in the performativity of the big data dream. We show that the belief in the dream is dispersed throughout the case organization, and that visualizations constructed by actors in the maintenance operations that make use of big data are negatively received. Specifically, we show that maintenance analysts craft and try to disseminate a particular tool—the Maintenance Analysis Tool EnergyCo (MATE)—which calculates and visualizes areas with potential for improvement and recommendations for changes in maintenance practice. However, their efforts are doubted and framed as a misuse of digitalization and big data by certain actors in the maintenance process.

Based on these findings we make two contributions to the literature. First, the big data dream of scientific management 2.0 offers an opportunity to repurpose accounts. When more data is made available, more visualizations can be produced for management (Ronzani & Gatzweiler, 2021). However, these visualizations do not merely supplement traditional accounting numbers by enhancing the accuracy of measurement, predictions, and human judgement (Appelbaum et al., 2017; Vasarhelyi et al., 2015; Warren et al., 2015), but present a critique of their usefulness. Second, the case highlights that accounting and big data rest on different philosophical underpinnings that can come into conflict. When big data is to be used in practice, people must make conscious, value-laden choices about relevancy, which makes the dream of scientific management 2.0 crumble. This offers an indication of how accounting limits the performative power of big data in certain circumstances. Hence, we argue that the relationship between big data and accounting is mutually constitutive.

Article 1 contributes to the dissertation's overarching research aim by showing that the accounting craft and big data intertwine in a mutually constituting relationship to disclose objects for the optimization of maintenance practice. However, such objects may be contested. Accounting contributes to the tensions by imbuing ostensibly objective data with a particular order. When big data is imbued with order or relevance, it loses its innocence and becomes a vehicle for political ambitions. The result is the breakdown of the dream of objective and adaptive management.

B. Article 2—Concealed Pathways: How the Visibility of Links in a System of Inscriptions is Influenced

As previously discussed, the second article was the last to be developed. However, as it primarily targets an audience of accounting scholars, it is presented prior to Article 3. The article investigates how a specific property of material pathways linking accounting inscriptions—visibility—is influenced. The motivation for the article rests on the simple empirical observation that contemporary organizations rely on documents like reports, lists, tables, and graphs to realize their objectives (Jordan et al., 2018; Qu & Cooper, 2011; Quattrone, 2009). This is also the case in EnergyCo's maintenance operations. Systems of interlinked documents are needed because single documents rarely disclose all of the necessary information (Jordan & Messner, 2012). Increased reliance on disordered systems for (big) data collection, storage, analysis, and visualization has made it increasingly possible to assemble and re-assemble systems of interlinked documents to disclose new objects that, in turn, can be used for management (Kornberger et al., 2017).

Although accounting research has inquired into how singular inscriptions (Latour, 1987; Robson, 1992) shape organizational realities, systems of interconnected inscriptions and the links that glue them together have received less attention. One notable exception is Martinez and Cooper (2019), who theorize systems of inscriptions as linked through "visual pathways" (p. 2)—materially inscribed guides and instructions for engaging with the system. However, although the authors highlight that the *visual* properties of links matter for engagement, there is still a need to elaborate on how the visibility of links is influenced. If visual properties of links are "central for [the] calculative functionalities" of systems of inscriptions (Martinez & Cooper, 2019, p. 2), then the way in which visibility is influenced is also relevant. Hence, we ask:

How are the visual properties of links influenced?

The empirical findings from the EnergyCo case show how a system of interlinked inscriptions is constituted to disclose an (im)balance between financial performance and safety risk in the maintenance operations. However, although the system discloses objects that are meant to aid in the management of the tradeoff, it is unable to successfully balance the two concerns. It is difficult to carve out a cause for the system failure, but the concealment of pathways may be a contributing factor. The study shows how a specific social aspect—actors' capacity for specialized knowledge—contributes to the visibility or concealment of these material links.

This article's contribution to the literature is twofold. First, we show that the analysis of accounting inscriptions should not just be restricted to individual inscriptions. Instead, it should devote equal attention to understanding properties of links that bind them together in systems of management and the aspects that influence them. Second, while the material properties of visual pathways matter for users' abilities to engage with a system of interlinked inscriptions (Martinez & Cooper, 2019), we show how actors' capacity for specialized knowledge can contribute to the visibility or concealment of material pathways.

Article 2 addresses the overarching research aim by diving into the minutiae of how the accounting craft and big data intertwine to disclose new objects. Accounting and big data are brought together through relational systems of interlinked technologies and inscriptions to subsequently disclose new objects for management. The implication of accounting and big data intertwining is that the links holding together the system of documents for managing the tradeoff between financial performance and safety risk become concealed. Actors do not seem to have the specialized-knowledge capacity that is needed to visualize the links and subsequently engage with the system in order to balance the two concerns.

C. Article 3—Knowledge Gained, Knowledge Lost: The Paradox of Digitalizing Knowledge Work

As mentioned above, the final article is aimed at an IS audience. The reason for including this article in my dissertation is twofold. First, as a scholar interested in accounting and big data, I find myself at the intersection between two fields: accounting and IS. More, my engagement with the IS literature has been detrimental to my understanding of big data and other digital technologies. Therefore, I found it both reasonable and useful for understanding the relations between big data and accounting to aim for deeper engagement with this stream of literature. Second, although this article does not explicitly address accounting, it is still indirectly concerned with accounting issues, as it studies what happens as processes are digitalized. A key feature of digitalization is the proliferation of digital representations (Bailey et al., 2012; Newell, 2015; Zuboff, 1988), many of which can be categorized as accounting representations (Lowe & Koh, 2007). As such, the article and its contributions address the overarching research aim.

IS research has shown how digitalization allows organizations to gain knowledge based on data analytics, machine learning, and other technologies (Benbya et al., 2021; Yoo, 2010). In other words, when organizations engage in, for example, work related to collecting, storing, analyzing, and visualizing big data, they can disclose knowledge objects that were previously difficult to "see." However, research has also shown that extensive reliance on big data can entail a loss of knowing (Bailey et al., 2012; Faraj et al., 2018; Pachidi et al., 2020; Zuboff, 1988).

To further our understanding of this conundrum, we adopt a dialectical perspective (Benson, 1977; Hargrave, 2021), which allows us to analyze the continual management of tensions in the digitalization of knowledge work. Notably, tensions made salient by digitalization are not dissolved through organizational responses but can, in fact, become objectified through them (Hargrave & Van de Ven, 2017; Smith & Lewis, 2011; Van de Ven & Poole, 1995). Sometimes, the management of tensions through organizational responses can reify as a paradox in which "contradictory yet interrelated elements […] exist simultaneously and persist over time" (Smith & Lewis, 2011, p. 382). On the basis of a dialectical perspective on digitalization we ask:

How do tensions manifest in digitalizing knowledge work?

Based on the extant literature and empirical data, we identify three latent tensions—authority tensions, knowing tensions, and valuation tensions—related to digitalizing knowledge work, and analyze how they were constructed and manifested in the digitalization of EnergyCo's machine-maintenance operations. As a result, we show digitalizing knowledge work to be an inherently paradoxical process in which *increasing available data to improve task performance can simultaneously decrease the capability to perform the task effectively*.

The combination of our theoretical lens and empirical findings enables us to demonstrate how this paradox may spur spirals of unintended consequences during the digitalization of knowledge work. As such, we contribute to the literature on digitalizing knowledge work (Benson, 1977; Hargrave, 2021; Pachidi et al., 2020) by showing that this process involves three latent tensions of authority, knowing, and valuation. Moreover, through a process model of digitalizing knowledge work, our dialectical inquiry into the EnergyCo maintenance case enables us to show how such tensions are constructed and manifested, and then addressed through sociomaterial responses. More specifically, the model shows how a dialectical process involving tensions and responses interacts with and shapes digitalization trajectories.

Article 3 addresses the overarching research aim, albeit in a more indirect manner. The article assumes that digital representations (i.e., the material manifestation of the intertwining of big data and the accounting craft) proliferate as organizations go through digitalization processes related to, for example, knowledge work. Hence, the article focuses more on the implications of digitalization and the resulting dissemination of (accounting) representations. It highlights how the digitalization of knowledge work leads to the manifestation of tensions, which require responses. This dialectical process between tension manifestation and responses might objectify a paradox, as it makes knowledge work both more effective and less effective due to big data and the representations that are produced to make sense of it.

The purposes, research questions, methodologies and methods, findings, and contributions of the articles included in this dissertation are summarized in Table 1.

Table 1 *Purposes, research questions, methodologies/methods, findings, and contributions from the articles*

	Article 1	***Article 2***	***Article 3***
Purpose	Investigate the relationship between the big data dream of objective and adaptive management and accounting's propositions of relevance.	Investigate how a specific property of material pathways linking accounting inscriptions (i.e., visibility) is influenced.	Examine how digitalization allows organizations to gain knowledge based on big data and analytics technologies, while simultaneously entailing a loss of knowing.
Research question	How is the performativity of big data influencing or influenced by accounting?	How are the visual properties of links influenced?	How do tensions manifest in digitalizing knowledge work?
Methodology/method	Longitudinal, qualitative single case study.	Longitudinal, qualitative single case study.	Longitudinal, qualitative single case study.
Findings	The big data dream is dispersed throughout the case organization, and accounting visualizations constructed to make big data useful are received negatively.	We show how actors' capacity for a specific social aspect (i.e., specialized knowledge) contributes to the visibility or concealment of material links.	Three latent tensions related to digitalizing knowledge work and organizational responses are identified: authority tensions, knowing tensions, and valuation tensions.
Contribution	The relationship between big data and accounting is mutually constitutive. Big data leads to a proliferation of accounts, and accounting limits the performativity of big data.	Analyses of accounting inscriptions should devote attention to understanding the properties of links and the aspects that influence them. Moreover, actors' capacity for specialized knowledge can contribute to the visibility or concealment of material pathways.	The digitalization of knowledge work is a paradoxical process of multiple interacting tensions that may lead to spirals of unintended consequences.

IV. Concluding Discussion

A. Theoretical Implications

The aim of this dissertation is to investigate the interrelationship between accounting and the deluge of data, often referred to as big data (Kitchin, 2014). By adopting a view of accounting as a dynamic and organizational craft (Hopwood, 1987), I aim to understand *how the accounting craft and big data intertwine to disclose new objects as well as the implications of this interrelationship.*

To address this overarching research aim, I conducted a longitudinal qualitative case study of EnergyCo, a firm that has invested substantial amounts in the adoption of a disordered system (Constantiou & Kallinikos, 2015a; Weinberger, 2007) in order to collect, store, analyze, and visualize industrial big data with the aim of disclosing objects useful for improving its maintenance operations.

All three articles in this dissertation represent distinct but intertwined interpretations of the data material that emanated from the EnergyCo case, and each article sheds light on the overarching research aim in a unique way. Figure 2 provides an overview of the dissertation and the connections among the articles. However, I stress that Figure 2 is only an attempt to compartmentalize and visualize relationships and processes that are immensely complex. An attempt is made to illustratively place the articles within Figure 2 based on placement criteria related to their main areas of analytical focus. For example, although Article 1 addresses implications, its main analytical focus is on the interrelationship between accounting and big data in practice. Hence, it is placed between the "The big data dream" and "The accounting craft."

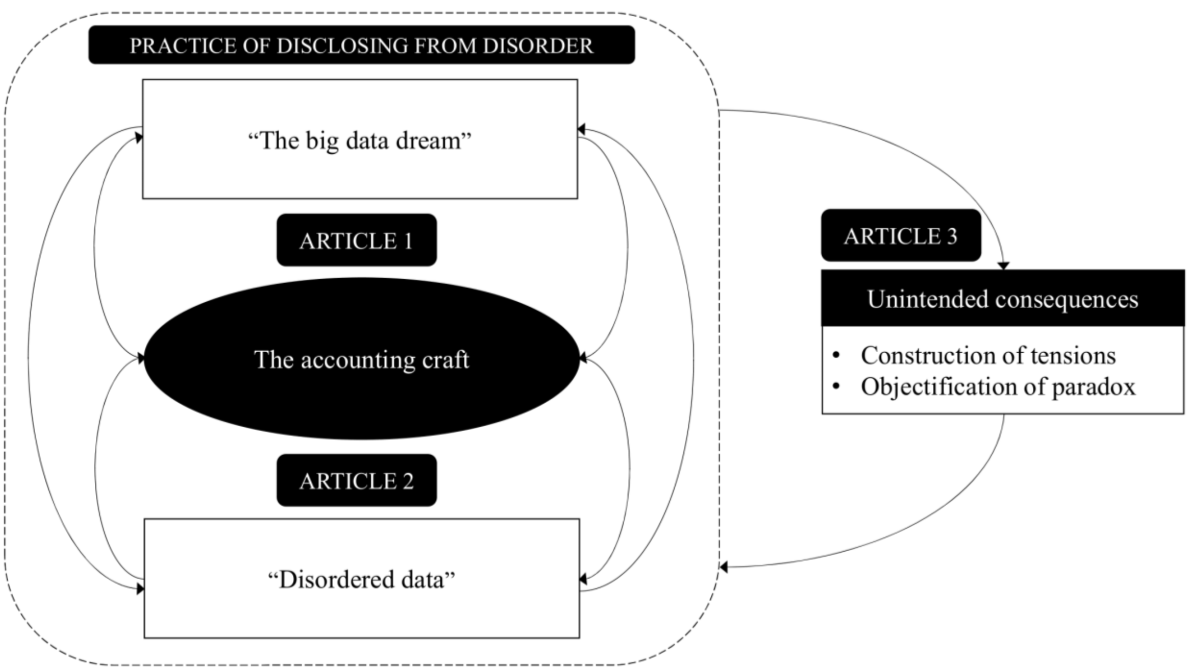

Figure 2 *Overview of articles in the dissertation and the connections among them*

Although the dream proposed in the big data discourse is that data should be allowed to “speak for themselves” (Kitchin, 2014, p. 3), this dissertation shows that this is a utopian ideal—data must be transposed into some ordered format to become useful. In other words, if data is to disclose new objects that organizational actors can use in relation to management, “raw” (Gitelman & Jackson, 2013) and big data must be crafted into accounting. In this regard, accounting and big data intertwine in a mutually constitutive relationship to disclose objects. Big data leads to the proliferation of accounting representations, and accounting imposes order on disordered big data to make it manageable. In practice, the accounting craft and big data are brought together through relational systems of interlinked technologies and inscriptions that are designed to disclose new objects for management. In the EnergyCo case, for example, accounting and big data intertwine to make objects like MATE and its visualization of aspects like “potential for improvement” appear in the organization’s maintenance process.

Furthermore, this dissertation shows that the practice of dealing with the disorder of big data to disclose managerial objects can lead to unintended consequences for organizations. Laboriously intertwining the accounting craft with big data to *make objects appear in order to generate alternatives for organizational intervention* might not put the organization on the trajectory that was envisioned prior to its investments in digital technology. In politicized settings, like EnergyCo’s maintenance operations, the ostensible post-political (Saifer & Dacin, 2021) and objective nature of big data is tainted by the order imposed by the accounting craft, making the objects that are disclosed subject to critique and dismissal by organizational actors. One element shown in this dissertation to contribute to the dismissal of disclosed objects is the difficulty of tracing their origins. Although the decoupling of accounting from what it is referencing does not always produce this effect (Dambrin & Robson, 2011), it seems to play a role in the EnergyCo maintenance context. For instance, the links between the observable accounting inscription (i.e., MATE) and the system to which it is connected are concealed by technology and actors’ specialized knowledge about that technology. Ultimately, this digitalization process in which actors in EnergyCo craft (accounting) representations to make big data useful for improving maintenance operations leads to the materialization of a paradox—increasing available data to improve task performance in maintenance simultaneously decreases the capability to effectively perform maintenance tasks.

As such, the dissertation contributes to the stream of research on how accounting is crafted to disclose in environments characterized by data deluge and disordered systems (Kornberger et al., 2017; Quattrone, 2016). Through three empirical accounts of accounting and big data intertwining in action, we learn that they are wrapped up in a mutually constitutive relationship to disclose new objects, but that the implications of this interrelationship can be paradoxical. Big data makes accounting proliferate and, as a result, opens up "a plane of possibilities that did not exist beforehand" (Kornberger et al., 2017, p. 91; Lury & Marres, 2015). However, the objects that are disclosed do not automatically mobilize actors for action, leaving the potential of big data untapped.

B. Practical Implications

This dissertation has several practical implications, two of which are highlighted here. First, managers in organizations and society should approach projects aimed at harnessing big data with realistic expectations about the likely outcomes of such endeavors. Although consultants and industry commentators present big data as a technological "silver bullet" offering ample opportunities to reduce costs, make faster and better decisions, and develop new products and services (Anderson et al., 2008; Davenport et al., 2012), the research presented in this dissertation points to the possibility that such endeavors could have unintended consequences. In fact, rather than streamlining operations and making them more efficient and effective, digitalization might lead to less efficient and effective operations. Managers in organizations with strong professional and political tensions should be particularly mindful. Second, and relatedly, managers should not treat the decision information that emanates from big data analyses, which is referred to as "objects" in this introductory chapter, as objective and neutral. This information does not offer facts that members of the organization will respond to without question. Rather, as shown throughout the articles in this dissertation, this information might be doubted, discarded, or even used as "ammunition" (Burchell, Clubb, Hopwood, & Hughes, 1980, p. 14) in internal political disputes. As such, although the production and use of management information based on big data is widely believed to provide a factual basis for decisions, this dissertation shows that facts are not always accepted. Therefore, relying on big data as a basis for decisions might give rise to internal tensions rather than settle disputes.

V. Limitations and Future Research

This dissertation shows how objects disclosed by the intertwining of the accounting craft and big data are disputed and lead to unintended consequences. The influence of political and professional tensions on this outcome should not be underestimated. They might, in fact, be the most prominent reasons why technologies like big data fail to have a material effect in certain areas of the organization. Hence, to further extend our understanding of the relationship between the accounting craft and big data, studies of these technologies in contexts that do not carry this type of political legacy are needed. In such contexts, the objects that are disclosed might engender different responses from organizational actors and subsequent effects might not be as intended.

VI. References

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VII. Appendix

Table 2 *Overview of interviews in EnergyCo*[1,2]

Interviewee	***Interviews and follow-ups***	***Duration (Approx. hh:mm)***
Maintenance Analyst Team Leader	5	01:30; 01:30; 01:38; 00:30; 00:35
Senior Performance Analyst	3	02:00; 01:30; 01:45
Maintenance Analyst D	3	00:53; 00:57; 00:16
Senior Maintenance Engineer	2	01:00; 01:00
Maintenance Analyst A	2	01:30; 01:00
Maintenance Controller	1	00:56
External Maintenance Consultants	1	02:00

[1] The names assigned to interview subjects vary across articles due to different theorizations of the data. The same number of interviews is used in the theorization of each article, although different interviews are drawn on more extensively in the various articles.

[2] Two interviews were group interviews with two or three interview subjects present. Hence, although there were 43 interactions with interview subjects, only 40 interview sessions were conducted. The first group interview included Senior Maintenance Engineer A and the Safety Representative. The second included the Senior Performance Analyst, the Maintenance Analyst Team Leader, and Maintenance Analyst A.

Safety Representative	1	01:00
Maintenance Operations Engineer A	1	00:50
Maintenance Operations Engineer B	1	00:53
Maintenance Analyst B	1	01:05
Data Governance Manager	1	01:00
Maintenance Analyst C	1	00:55
Maintenance Analyst E	1	01:00
Maintenance Analyst F	1	01:16
Maintenance Analyst G	1	01:20
Maintenance Analyst H	1	01:04
Maintenance Analyst I	1	00:58
Maintenance Expert Team Leader A	1	00:39
Maintenance Expert Team Leader B	1	00:41
Integrated Operations Center Leader	1	00:45
Maintenance Operations Team Leader A	1	00:56
Maintenance Expert Team Leader C	1	00:43
Maintenance Expert A	1	00:37
Maintenance Expert Team Leader D	1	00:58
Maintenance Operations Team Leader B	1	01:03
Union Leader	1	00:56
Operations Electrician	1	01:19
Maintenance Operations Team Leader C	1	01:03
Predictive Maintenance Team Leader	1	01:00
Predictive Maintenance Analyst	1	00:56
Maintenance Analyst J	1	01:01
Maintenance Expert B	1	01:25
SUM	**43 (40 interview sessions)**	**41:53**

Chapter 1

The Dream of Big Data: The Role of Accounting in the Performativity of a New Technology

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Abstract

This article investigates the relationship between big data and accounting by analyzing efforts to mobilize big data and visualization technologies to optimize the maintenance processes in an international energy company, EnergyCo. Big data is closely linked to a persuasive proposition about the value of large and varied datasets, and their potential to provide solutions across time and space and in the face of an inherently unknowable future. This proposition produces a dream of management that is both objective and adaptive—a managerial style we label the "big data dream of scientific management 2.0." The big data dream creates a challenge for accounting through its conception of "relevant" information. The data should not be imbued with relevance. Instead, relevance should emerge inductively. Through a case study, we investigate the role of accounting in the performativity of the big data dream. We show that the belief in the dream is dispersed throughout the case organization, and that visualizations constructed by actors in the maintenance operations in order to make use of big data are negatively received. Based on these findings, we argue that the relationship between big data and accounting is mutually constitutive. Big data allows for new visualizations to emerge, but these visualizations also imbue ostensibly objective data with a particular relevance, leading to a breakdown of the dream. This analysis allows us to contribute to the literature by showing that big data not only improves current accounting numbers, but also leads to a repurposing of accounts. In addition, we demonstrate that accounting and big data rest on different philosophical underpinnings. In politicized settings, this may lead to accounting limiting the performativity of big data.

Keywords: Accounting, big data, performativity, case study, maintenance

1. Introduction

This is really misuse of digitalization because digitalization and automation are very good. […] [When] you want a certain result and then do some magic with the input data to get the output you want, it becomes dangerous. (Offshore Electrician)

This article investigates the relationship between big data and accounting, a topic that has received a notable amount of attention from accounting scholars. Big data is of interest, in part, because it is assumed to afford enhancement of existing accounting numbers which, in turn, is expected to increase the accuracy of measurements, predictions, and human judgements (Appelbaum et al., 2017; Vasarhelyi et al., 2015; Warren et al., 2015). Moreover, in order to make big data "understandable and actionable" (Ronzani & Gatzwailer, 2021, p. 1), there has been a surge in visualizations to accompany the new practices of collecting and storing data (Arnaboldi et al., 2017; Salijeni et al., 2021). Accounting and big data seem to play mutually constitutive roles in the digital revolution evident in organizations and society (Quattrone, 2016).

However, big data should be conceptualized analytically as something distinct from accounting. It is both an object and a process (Arnaboldi et al., 2017) deeply linked to a mythological (Meyer & Rowan, 1977) proposition about the value of large and varied datasets and the solutions they can generate. The proposition suggests that by collecting and storing *all* data, answers can inductively "emerge" from the empirical world without a need for specific queries up front (Kitchin, 2014). Data should be valued for its own sake, as it can become "useful at a later point" (Constantiou & Kallinikos, 2015a, p. 13). The myth of big data and the related discourse is persuasive, and even subject to "fetishization" because it is believed to aid organizations facing an essentially unknowable future (Schwarzkopf, 2020, p. 199). Hence, organizations "believe they should be in the data collection business" (Fourcade & Healy, 2017, p. 16), although they do not always know why.

Through this proposition, the big data myth encroaches on ideas about the management of organizations and society. It attaches itself to the rigor of science (Chua, 2019) through its link to objectivity[3] but it simultaneously declares the end of theory (Anderson, 2008), as it refuses to subdue to notions from existing theory or preconceived categories (Alaimo & Kallinikos, 2020).

[3] The word "data" is frequently conflated with "facts," "evidence," "information," and "knowledge" in everyday language, even though data is often conceptualized as a neutral prerequisite for these other terms (Rosenberg, 2013).

As such, big data is presented as an objective and post-political technology (Saifer & Dacin, 2021) that is particularly well-suited for a constantly shifting environment. In this regard, the big data myth contributes to the constitution of the dream of scientific management 2.0 in which management can be both objective and adaptive. This suggests that current managerial problems are related to ‘management-without-objectivity’ and ‘management-without-adaptivity.’ Humans and machines play a conjoint role in this dream, as datasets are ideally fed to hungry and apparently objective algorithmic machine intelligence that can detect patterns invisible to humans (Fourcade & Johns, 2020). In its ideal expression, the dream of scientific management 2.0 is a type of management in which technology provides novel and objective insights into human actors.

In contrast to arguments suggesting that more data improves accounting numbers (Appelbaum et al., 2017; Vasarhelyi et al., 2015; Warren et al., 2015), the big data dream of scientific management 2.0 poses a challenge to current theoretically deduced objectives of accounting systems, like producing relevant accounts of a selection of data for preconceived user groups (Johnson & Kaplan, 1987; Power, 2010; Young, 2006). In “the ocean of data” (Quattrone, 2016, p. 3), new ways of conceptualizing relevance reside and, in turn, foster opportunities for the continuous repurposing of accounting numbers and practices. The “burgeoning of visual artifacts and technologies” (Ronzani & Gatzweiler, 2021, p 1) is an indication of this flexible approach to accounting that is already widely practiced. However, traditional accounting concepts and practices seem somewhat resilient, even when faced with the opportunities provided by these new technologies (Arnaboldi et al., 2017; Salijeni et al., 2021). Therefore, even if accounting objectives like “relevance” and “preconceived user groups” are at odds with the main proposition of the dream of scientific management 2.0, they are powerful notions that human actors must draw on to interpret and interact with big and disordered (Weinberger, 2007) datasets.

Consequently, the performativity of the big data dream seems to be at least somewhat reliant on these notions, as people frequently mobilize accounting concepts in their day-to-day activities. This form of intertwined and contingent performativity has been argued for conceptually (Arnaboldi et al., 2017; Quattrone, 2016) but few empirical studies have examined these assumptions. We hence ask the following research questions:

How is the performativity of Big data influencing or influenced by accounting?

To analyze how the big data dream of scientific management 2.0 performs social reality, we draw on the performativity literature (Austin, 1962; Butler, 2010; MacKenzie, 2006). Originally coined to describe how utterances come to constitute reality (Austin, 1962), the concept of “performativity” provides a theoretical lens through which the unpredictable and contingent constitution of the social world can be explored (Butler, 2010). Performative utterances are not restricted to human beings—material devices also have “voices.” In other words, things like formulas, models, and accounting inscriptions are not merely cameras depicting some underlying reality—they are engines that produce it (MacKenzie, 2006). Accounting researchers have long highlighted the importance of material technologies for translating societal programs into practice (Miller & Rose, 1990; Robson, 1994). That is, the performativity of societal dreams can be analyzed by carefully examining the material in which these dreams are inscribed and the actions the material engenders as people interact with it (Pollock & D’Adderio, 2012; Salijeni et al., 2021). Therefore, to understand how ideas like the big data dream of scientific management 2.0 succeed or fail in shaping the world, we should examine the accounting that is constructed in its name.

Empirically, this article analyses the introduction of practices for collecting, storing, and visualizing big data in EnergyCo, a global energy company mainly operating in the petroleum industry. The Norwegian Continental Shelf constitutes the largest and most mature business area for the company. It is populated by offshore oil rigs of varying production capacity and age. The maintenance operation for these rigs was chosen as our focal research area for two main reasons. First, EnergyCo believed this area had significant potential for improvement through utilization of big data. Despite earlier efforts to lower costs, costs were rising and the extant accounting systems did not seem sufficient for improving performance. The visualization of big data was viewed, at least indirectly, as a remedy for this failure of the extant accounting systems. Second, the maintenance operations consisted of highly distinct communities of practice—offshore and onshore maintenance operations. For changes to occur, big data and accounting needed to coproduce a visualization that mediated the concerns of these communities. Hence, the maintenance operations are suitable for highlighting the role of accounting in the performativity of the big data dream of scientific management 2.0.

We present two main findings from the empirical investigation. First, we find that the belief in the big data dream of scientific management 2.0 was dispersed throughout the organization. In other words, the discourse linked to the dream has had performative effects on the organization in terms of "preparing the ground," both materially and mentally, for a new form of accounting and action. Second, we show that the visualizations constructed by the actors in the maintenance operations and elsewhere to operationalize the big data dream were negatively received by certain groups of actors. Accounting is needed to move towards the dream, but it can also make that dream break down.

Based on these findings, we make two contributions to the literature on accounting and big data. First, the big data dream of scientific management 2.0 offers an opportunity to repurpose accounts. When more data is made available, more visualizations can be produced for management (Ronzani & Gatzweiler, 2021). These visualizations do not merely supplement traditional accounting numbers by enhancing the accuracy of measurements, predictions, and human judgements (Appelbaum et al., 2017; Vasarhelyi et al., 2015; Warren et al., 2015). They also present a critique of their usefulness in relation to aspects like cutting costs. Second, our case demonstrates that accounting and big data rest on different philosophical underpinnings that can come into conflict. When people (not machines) operationalize big data in practice, they must make conscious choices about relevance, which makes the dream of scientific management 2.0 crumble. In this regard, accounting, in certain circumstances, limits the performative power of big data because it is at odds with the ideal of "inexhaustibility" (Arnaboldi et al., 2017, p. 765).

As such, our analysis provides empirical evidence that helps respond to conceptual claims in the literature on accounting and big data. We have no reason to doubt that the repurposing of accounts in the form of new visualizations will continue, as there is a need to make sense of increasingly big datasets. However, as expressions of the accounting notion of relevance for a user group, these visualizations can be at odds with the pure propositions of scientific management 2.0 and, thus, have the potential to prevent the reification of the dream in practice. Who constructs accounting and how they do so matters for the performativity of the dream. Our case provides empirical evidence of the paradox of the digital revolution (Quattrone, 2016), as it shows that it produces a strong belief in the possibility of rational management but simultaneously augments uncertainty and reifies existing distances (Quattrone & Hopper, 2005).

The remainder of this article proceeds as follows. In the next section, we present an argument for the existence of a big data dream in society and organizations, which is followed by an overview of the performativity literature. Thereafter, we discuss our research methods and present the case organization. We then present our empirical findings before we discuss those findings and provide suggestions for future research.

2. Theoretical Foundation: The Big Data Dream and Accounting

2.1 The Big Data Dream of Scientific Management 2.0 and its Challenge for Accounting

Societal discourse increasingly includes warnings about the potential perils of big data. Scholars and commentators point to the possibility that big-data accumulators could gain power and limit individual freedom through behavioral manipulation (Zuboff, 2015; 2019), the potential for big data and algorithms to reinforce existing biases and power structures in society (O'Neil, 2016), and the challenges related to redistribution of the spoils produced through the use of big data and artificial intelligence (Brynjolfsson & McAfee, 2016). However, this has not scared organizations away from investing heavily in practices of collecting and storing big data in the hope of reaping some of its ostensible benefits. To understand this situation, we need a broad conceptualization of big data, especially its mythological underpinnings.

Big data is more than the voluminous and varied datasets that are stored in disordered technical infrastructures (Weinberger, 2007). It is underpinned by a desire "to capture entire populations or systems (n=all)" (Kitchin, 2014, p. 1). It is both an object and a process (Arnaboldi et al., 2017). The substantial effort related to the process of capturing it "all" is considered worthwhile because of the myth linked to big data:

> [T]he widespread belief that large datasets offer a higher form of intelligence and knowledge that can generate insights that were previously impossible, with the aura of truth, objectivity, and accuracy. (boyd & Crawford, 2012, p. 663)

This big-data myth has become institutionalized and has performative effects through, for instance, professions, programs, and techniques (Meyer & Rowan, 1977, p. 344). Certain professions (e.g., auditors) often exert a pull for big-data collection based on normative and moral claims—we collect big data because we must (see, e.g., Appelbaum et al., 2017). Moreover, societal programs about organizational appropriateness engender mimetic behavior—we collect big data because everyone else does. Finally, technological development enables the practice—we collect big data because we can. It seems uncontroversial to claim that contemporary organizations are shaped by the "[big] data imperative" (Fourcade & Healey, 2017, p. 14) of collecting as much data as they possibly can. They "believe they should be in the data collection business" (Fourcade & Healey, 2017, p. 16), even if they do not know what to do with that data.

Schwartzkopf (2020) theorizes that organizational *ignorance* is a reason for the dissemination of organizational practices of collecting and storing excessive amounts of data. In his conception, ignorance is a paradox, as it is not only produced by the absence of data and information but also their excessive presence. Ignorance, then, is "sacred" (Schwartzkopf, 2020, p. 197), both "feared and worshipped" (Schwartzkopf, 2020, p. 210) because it is simultaneously undesirable and valuable. Big data (i.e., the excess of data) is turned into a "fetish" (Schwartzkopf, 2020, p. 198) by actors in data-intensive industries because it can induce and reproduce ignorance in organizations. In other words, the "essential unknowability of the future" (Schwartzkopf, 2020, p. 211) organizes data-intensive industries and pushes organizations to engage in the collection and storage of big data. Whether caused by the absence or excessive presence of data, the unknowable future is a powerful force that makes organizations engage in the collection and storage of big data.

Organizations seem to view their efforts to collect "all" data as worthwhile. The big-data myth is a powerful performative force. The myth proposes that data should be collected and stored because it can become "useful at a later point" (Constantiou & Kallinikos, 2015a, p. 13) for "generat[ing] insights that were previously impossible" (boyd & Crawford, 2012, p. 663) in the face of the essentially unknowable future (Schwartzkopf, 2020). However, at some point, the future turns into the present. A situation that must be managed. And management based on big data is presumably different than management without it for at least three reasons.

First, big data is the latest "expression of the longstanding efforts towards quantifying quality" (Monteiro et al., 2018, p. 3). Qualities that have previously "remained stubbornly beyond the reach of this transformation" (Monteiro et al., 2018, p. 2) have been brought into the quantitative realm. Liberal democracies persist in the belief in "objectivity" in which depersonalized and apolitical knowledge—or quantitative evidence—should underpin decisions in society and the organizations within it (Chua, 2019). Big data lends itself to notions of objectivity because it is quantitative rather than subjective. This highlights the link between notions of scientific rigor and big data, although it hails the value of "new epistemologies" (Kitchin, 2014, p. 1) rather than established scientific methods that rely on theories, hypotheses, and deductive reasoning (Alaimo & Kallinikos, 2020;

Anderson, 2008; boyd & Crawford, 2012;). Management based on big data can be scientifically grounded and post-political, albeit in a novel way (Saifer & Dacin, 2021).

Second, big data is about discovering new things. As boyd and Crawford (2012) explain, "Big Data is less about data that is big than it is about a capacity to *search*, *aggregate*, and *cross reference* large datasets." (p. 663, emphasis added). The answer is not found in a single structured database, but in the relations among all types of data. Big data is a new approach that "stakes out new terrains of objects, methods of knowing, and definitions of social life" (boyd & Crawford, 2012, p. 665). In other words, it is about moving beyond what we know when facing the unknown (Schwartzkopf, 2020). We cannot draw on what we know in order to handle what we do not know. Hence, big data proposes its own philosophy of no need for philosophy (Berry, 2011) and frees us from restrictions in order to manage an uncertain future. Therefore, management based on big data is an adaptive practice.

Third, big data is ideally used in machine-led management where technology provides human actors with novel and objective insights. Due to big data's exhaustive scope, variety, and volume, humans struggle to make sense of it. However, for machines, excessive amounts of quantitative data present opportunities. Machine learning algorithms are hungry (Fourcade & Johns, 2020) for data. They are the fuel for practices focused on "automating the discovery of rules and patterns from data, however dispersed and heterogeneous it may be, and drawing inferences from those patterns, without explicit programming" (Fourcade & Johns, 2020, p. 804). The vison of being able to let lose hungry, 'objective' machines that can assist in navigating the unknown draws organizations towards practices of excessive data collection and storage, although most companies do not yet possess these technological solutions.

Through the interplay among increasingly quantified qualities, an unknowable environment that cannot be managed using extant knowledge, and visions of machines that can aid in the sensemaking of excessive datasets, big data proposes a dream of a new approach to management. We label this dream "scientific management 2.0"—a proposition that management can simultaneously be objective and adaptive. In its ideal expression, scientific management 2.0 is a type of hands-off management in which humans are expected to stand back and let technology lead the way in the management of the unknown.

The big data dream of scientific management 2.0 encroaches on extant management practices, especially practices rooted in "canons of procuring structured information of lasting value that addresses specific and long-term organizational objectives" (Constantiou & Kallinikos, 2015a, p. 1). Accounting practices, for example, are underpinned by theoretically deduced objectives, like producing "useful" and "relevant" accounts of a selection of data for preconceived user groups. This ambition is probably most explicitly formulated in relation to financial accounting. Through the performative influence of financial economics, financial accounting standard-setters have gradually transformed reports to align them with market-based principles (Power, 2010). As a result, the taken-for-granted purpose of financial accounting has shifted to providing user groups of investors and creditors in capital markets with information that is *relevant* to them (Young, 2006). Managerial accounting systems are envisioned as striving towards similar ambitions of producing information relevant for managers involved in decision-making activities related to organizational strategy and operations (Johnson & Kaplan, 1987). In other words, both managerial accounting and financial accounting are concerned with the relevance of information for preconceived user groups (e.g., managers, investors, creditors, tax authorities).[4]

In contrast to some arguments presented in the literature, the theoretically deduced objectives of relevancy for preconceived user groups in accounting are mainly a challenge in relation to what we have conceptualized as the big data dream of scientific management 2.0. Big data, the argument suggests, will enhance traditional financial data and lead to better measurements, more accurate predictions and prescriptions, the mitigation of human bias in judgement, and a shift towards more objectivity in evaluations and decision-making (Appelbaum et al., 2017; Vasarhelyi et al., 2015; Warren et al., 2015). This implies that certain accounting objectives can be achieved more effectively because big data makes things visible that previously were difficult to measure. For example, big data is believed to mitigate accounting measurements' loss of informational value for firms with higher intangible intensity by allowing for real-time, user-friendly visual disclosure (Vasarhelyi et al., 2015). Moreover, the use of big data is considered a plausible solution to the

[4] As a tangible example, the widely disseminated profit/loss statement is structured according to the priority of the claims to a firm's cashflow. The operating profit of a going concern is first subject to claims from creditors and then to claims from tax authorities. Thereafter, after-tax net profit (retained earnings) is distributed to eligible stockholders (e.g., investors). The accounting report is deliberately structured to provide relevant financial information to a set of predefined user groups operating in a market economy.

long-standing conflict among accounting standards related to fair-value accounting. Through the deployment of software-based robots that crawl the internet in search of “all relevant web-based information” (Warren et al., 2015, p. 403), fair-value estimates become more accurate and objective.

However, there are also arguments indicating that big data extends the borders of accounting. In “the ocean of data” (Quattrone, 2016, p. 3), “relevance” can be recast at will. As Bhimani and Willcocks (2014) state:

> What comprises relevant information and the presumed sequence of its deployment vis-a`-vis management action in the organisationally networked world has to be reconsidered. (p. 475)

In a digital world, accounting can be continuously repurposed and venture into new spaces (Hopwood, 1992). The “burgeoning of visual artifacts and technologies” (Ronzani & Gatzweiler, 2021, p. 1) is an indication that this repurposing of accounting is already widely practiced.

Some empirical studies examine how accounting and big data intertwine in practice. Salijeni et al. (2021) provide some evidence suggesting that although traditional accounting numbers and practices have not been eradicated by the advent of big data, they have changed. They show that the adoption of big data analytics (BDA) tools in auditing was confusing for many auditors, as it blurred the lines between what they knew auditing to be and what BDA enabled it to become. This resulted in practices of “over-auditing” (Salijeni et al., p. 3) in which new and extant audit practices were performed in combination. Arnaboldi et al. (2017) study the use of performance measures emerging from social-media data. They find that finance professionals do not view this information as relevant for their practice and leave such metrics in the hands of the marketing department. In other words, rather than accounting objectives being wiped away, those involved in accounting fortify and protect themselves from the big data “threat.” However, these studies seem take the performativity of the big data dream for granted. In contrast, our study aims to unearth *how* this ideal attach to practice and the role that accounting plays in that process.

In the big data dream of scientific management 2.0, there is no room for a priori accounting objectives. However, accounting numbers and practices “die hard.” Even if they are at odds with the dream’s propositions, they are powerful notions that actors draw on to interpret and interact with the world. As such, the performativity of the big data dream seems to be somewhat reliant on notions from accounting, as people frequently mobilize them. There appears to be a form of intertwined and contingent performativity between accounting and big data (Arnaboldi et al., 2017; Quattrone, 2016).

2.2 Analytical Framework: The Performativity of Discourse and the Material

Social reality is largely constructed and language plays an important role in the construction process (Berger & Luckmann, 1966). To add specificity to this general claim, Austin (1962) delineates between two types of speech acts: the declarative (descriptive) and the performative. The latter alludes to utterances that bring things into existence, either by certainty or when certain conditions are in place. Butler (2010) elaborates on this distinction between utterances with certain outcomes (illocutionary performatives) and contingent outcomes (perlocutionary performatives). She suggests that for certain outcomes to occur, a powerful sovereign must be behind the utterance—a situation that that is rarely found in social reality. Instead, utterances tend to have "limited performative agency" (Butler, 2010, p. 152). They are perlocutionary performatives that:

> [D]o not bring a phenomenon into being or act as a creator in that sense. Rather, they function performatively, which means that certain kinds of effects can possibly follow if and only if certain kinds of felicitous conditions are met. (Butler, 2010, p. 152)

Extending the analysis beyond "specific, individual utterances," MacKenzie (2006, p. 16) connects the concept of performativity to financial economic theory and the material devices emanating from it. Through an analysis of the effects of the Black-Scholes pricing model on the options market, he shows that utterances can be performative to different degrees, with the most powerful shaping processes in the image of the description provided by the utterance (i.e., "Barnesian" performativity). Therefore, material expressions of theory have the potential to be not merely cameras depicting some underlying reality, but engines producing reality. Butler (2010) criticizes MacKenzie for not specifically highlighting the performativity of the Black-Scholes pricing model as perlocutionary, but they both seem to agree that performativity is not the effect of utterances from single objects—rather, there are "broad networks" (Butler, 2010, p. 151) or "infrastructures" (MacKenzie, 2006, p. 12) of practices, material devices, and discursive elements that produce utterances that, in turn, shape the world.

Accounting is a material device that plays an important role in such networks in liberal democracies (Miller, 2001). These calculative assemblages (Martinez & Cooper, 2019) in which accounting is a particularly important element due, in part, to its perceived objectiveness (Porter, 1995) are involved in the constitution of organizations and society, and in the translation of societal programs into practice (Miller & Rose, 1990; Robson, 1994). As a result, accounting scholars claim that to understand the performativity of ideas and ambitions in society, one must pay attention to the calculative devices that play an important role in these performative networks (Pollock & D'Adderio, 2012; Salijeni et al., 2021). In turn, to understand how big data succeeds or fails in shaping the world, we should examine the accounting representations that are constructed in its name.

In this article, we draw on the notion of perlocutionary performativity and, in accordance with the extant accounting and performativity literature, highlight that the success (or failure) of ideologies to shape the world is contingent on accounting representations (Miller & Rose, 1990; Pollock & D'Adderio, 2012; Robson, 1994;) and a set of "felicitous conditions" (Butler, 2010, p. 152). We now turn to on our empirical investigation.

3. Research Methods

3.1 Case Description

EnergyCo's operations predominantly revolved around the extraction of oil and gas, and were mainly situated offshore in the challenging Arctic environment. Production was divided between 40 EnergyCo-operated fields and 10 partner-operated fields of varying production capacities and ages. Operations employed the majority of the firm's workforce (more than 21,000 people) and contributed about three-quarters of the firm's total revenue.

At the time of our study, the firm divided the workforce between onshore and offshore personnel. The onshore organization provided a range of services to the offshore organization, including finance and control, analyses, and planning. The onshore workforce was dominated by engineers and was highly educated relative to the offshore organization. It consisted of analysts in charge of analyzing operational data and presenting improvement suggestions, and planners responsible for planning maintenance, who were in contact with the offshore personnel. The offshore workforce mainly included vocationally educated technicians, many of whom had extensive experience.

Although the onshore-offshore dichotomy should not be interpreted as a sharp and hostile division, there was a gulf between these two worlds. The difference was particularly evident on safety-related issues, as the offshore community highlighted the importance of sentient and experience-based knowledge for managing safety risks, while the onshore community primarily valued the application of analytical expertise to operational data. As such, EnergyCo was an organization in which different rationales had to be continuously mediated—a type of work that is not always easy.

The Norwegian state was the majority owner of EnergyCo, with 67% of the shares. Therefore, the social-democratic philosophy underpinning Norwegian society was reflected in the state's expectations of the organization. On the one hand, the ownership offered the potential for substantial supplements to state finances. On the other hand, the state was a particular owner (Jones & Baumgartner, 2005) with an explicit ambition that the firm, in addition to producing value for its shareholders, should conduct its business in a responsible manner. Not surprisingly, EnergyCo was dedicated to such societal and organizational goals as safety, efficiency, and sustainability.

The close ties to the Norwegian state and its political philosophy were reflected in EnergyCo's management-control system. Beyond Budgeting principles (Bourmistrov & Kaarbøe, 2013) framed a complex package of controls (Malmi & Brown, 2008), including vast amounts of non-financial information (Vaivio, 2004). Top management defined overarching strategic goals but delegated the design of performance measures to the local organizational units. Therefore, employees in EnergyCo were considered responsible and able people who both could and wanted to accept responsibility and accountability. Hence, the combination of local performance measures and corporate technologies for control (like bonus systems, value statements, costs, and resource allocations) constituted the organization's management.

Although the petroleum industry has historically been highly profitable, it is vulnerable to fluctuations in the oil price. For EnergyCo, the 2014 oil crisis was a wake-up call with regard to cost levels. The mix of historically high profit margins; the high-risk, Arctic-offshore operational setting; and the decentralized control system had seemingly resulted in an organization that did not sufficiently emphasize costs in its decision-making. In relation to management control, the accounting systems had not been able to keep costs under control. Substantial cost-cutting programs were initiated to address the problem, but costs began to rise again after a few years.

To address the accounting systems’ failure to prevent rising costs, a digital strategy was launched in 2017 to support overarching strategic ambitions. The backbone of the strategy was OMNIA, a non-relational data repository containing vast amounts of internal and external data relevant to EnergyCo’s operations. In this article, our organizational area of interest is the maintenance operations, a context that embodies the onshore/offshore divide, as the risks of Arctic offshore operations must constantly be balanced with efficiency concerns. A failure to achieve a balance between safety and efficiency could have very real consequences for human life and corporate financial performance. In addition, the maintenance process was identified as the main driver of the negative cost trend in the company. As we show below, a group of maintenance analysts made use of the opportunities arising from OMNIA to develop a digital tool known as the Maintenance Analysis Tool EnergyCo (MATE) aimed at optimizing maintenance. Through analyses of objective data, this group believed a “more correct” balance between safety and efficiency could be achieved. At the time of our study, MATE had been implemented in the organization and had top management’s support.

Contact with EnergyCo was established through initiation of a research project in the autumn of 2018. In the initiation phase, we engaged in conversations with the Chief Digital Officer (CDO) and the leader of the Finance and Control department, and contacts within EnergyCo were identified. Through a set of preliminary interviews, the maintenance process and the analysts emerged as an interesting case for studying the how big data and visualization technologies are mobilized in practice.

3.2 Data Collection and Analysis

A round of preliminary interviews was conducted from March 2019 to April 2019, followed by a three-week fieldwork period in October 2019. During that period, one of the researchers was continuously on site at EnergyCo. Supplementary data was gathered from February 2020 to September 2021.

Data was collected using different methods, although the largest set of data emanated from 40 semi-structured interviews, primarily involving maintenance analysts, planners, and representatives of offshore and onshore operational units. The interviews lasted between 15 and 120 minutes. Most interviews were recorded and transcribed, but not all interviewees were comfortable being “on the record.” In these cases, extensive notes were taken during the interview and key points were written down directly after the interview's completion. We asked the interviewees about their experience and current role in EnergyCo, and about their work practices, experiences with and perceptions of technologies in assisting them with their work, key performance indicators and accountability in their current role, and interactions with other groups within the maintenance operations. The goal of the interviews was to develop an understanding of different actors' views on digital technology in the maintenance process, and subsequently examine whether and how big data was used within EnergyCo in practice.

In addition to the formal interviews, we engaged in numerous, informal face-to-face conversations with different actors in the maintenance process. Most of these conversations occurred over lunch during the fieldwork period. They were useful for double-checking details and deepening our understanding of the maintenance process. Talking points considered relevant for developing theoretical and empirical concepts were recorded in a fieldwork journal. The journal was updated daily with analytical notes and questions as well as personal field notes and reflections (e.g., from the conversations).

In addition, we attended five formal meetings. Four took place in the maintenance analyst group, of which two focused on evaluations of performance and the progress of analysts' work, and one focused on strategic information and training. During the fourth meeting, we presented our empirical findings to the maintenance analysts. This presentation took place one month after the fieldwork ended and, thus, served as a means of validating our empirical findings using a group of central actors. The fifth meeting was a regular planning meeting held offshore. This meeting focused on work orders and maintenance plans. Finally, we collected and analyzed documents (see Appendix for a selection), most of which we could not bring off-site due to their sensitive content. Reflections on these documents were recorded in the fieldwork journal for further analysis at a later stage.

Due to the opportunities to revisit the empirical site, and take recursive jumps between theory and empirical material, we employed an abductive approach to data analysis (Timmermans & Tavory, 2012). This process sensitized us to potentially interesting theoretical phenomena over time. To allow such phenomena to emerge, we entered the field only consciously framed by the higher-order theoretical concepts of big data, management accounting, and control. In accordance with the abductive methodology, these concepts were our "cultured knowledge" (Timmermans & Tavory, 2012, p. 172), as they represented our position in the world as researchers with specific backgrounds and ambitions. We believe this allowed our empirical site to inform our theorization process without neglecting the conscious or unconscious presence of some theoretical categories guiding the researchers. These categories were useful, as they provided some initial, albeit loose, structure to the first interviews. Recursively moving back and forth among the field, our collected empirical material, and literature in three consecutive rounds provided "a way to check for faulty memory and cognitive biases [and] to sensitize different theoretical approaches" (Timmermans & Tavory, 2012, p. 176). In other words, we loosely held on to our initial theoretical categories, and remained open to the possibility of our empirical material moving us in new and unexpected directions with regard to the relevant theoretical phenomena.

The process produced an interpretation of EnergyCo's efforts to digitalize the company as an effort to connect itself to the theoretical proposition of big data that "all" data should be collected and stored even if there are no clear a priori use cases. However, in order to become a digital leader, the organization had to make the data relevant for organizational actors. A host of visualizations was developed for this purpose. Hence, our analyses eventually culminated in an interpretation that the empirical story could shed light on the relationship between the theoretical concepts of big data and accounting. We now turn to presenting this empirical story in detail.

4. Empirical Findings

The empirical findings are presented in three interconnected episodes related to the dream of big data and its performativity. The first episode highlights how the dream journeyed to all parts of the organization: top to bottom and onshore to offshore. The second episode traces the journey in the maintenance process, where a specific tool was developed to visualize big data. The new tool allowed certain previously hidden patterns in the maintenance practice to emerge and, in the opinion of the analysts, provided the objective "facts" needed to strike an efficient balance between safety and costs. The third episode shows that this visualization failed to link the dream of scientific management 2.0 to practice, as it was unable to mediate the interests of all actors in the maintenance process. Collectively, the episodes highlight how the performativity of the big data dream is closely linked to accounting.

4.1 Episode 1: The Big Data Dream of Scientific Management 2.0 is Performative

4.1.1 "We" Have a Dream

The general societal and political optimism surrounding big data was paralleled, if not exceeded, in EnergyCo. Notwithstanding the importance of digital technologies in the company's past, they had seemingly been recast in an even more positive light. The launch of a digital strategy in 2017 allocating NOK 3 billion (approximately USD 350 million) to "programs for digitalization" (int_doc_1) indicated a substantial financial commitment to the big data dream. Although cost-efficient operations were not the sole ambition of the strategy, it was an important motivation for the majority of the programs. The CEO highlighted this ambition for efficiency:

> A combination of digitalization, standardization and a culture for continuous improvement may drive cost reductions, and form the basis for increased value creation and activity. (CEO EnergyCo, int_doc_1)

In the context of EnergyCo, digitalization entailed, inter alia, investing in new technical architectures and processes for collecting and storing big data. Hence, to enable the "programs for digitalization," OMNIA—a non-relational data repository containing vast amounts of internal and external data relevant to EnergyCo's operations—was implemented as an essential part of the digitalization strategy:

> OMNIA is a cloud-based data platform at the very heart of our work that enables seamless access to relevant data across disciplines. It is the foundation for creating even more value from our vast amounts of data. (Vice President of IT in EnergyCo, int_doc_5)

It was not only the volume (28 petabytes stored annually) that made the data in EnergyCo "big" but also *how* it was stored. The combination of large data volume, the non-relational character of OMNIA in which both structured and unstructured[5] data was stored for their potential future value, and the speed with which that data could be seamlessly retrieved justified this characterization. OMNIA was constructed to enable the organization to "*search*, *aggregate*, and *cross reference* large data sets" (boyd & Crawford, p. 663, emphasis added). OMNIA allowed EnergyCo to start dreaming about unlocking the potential in big data or, in other words, rethinking relevance in light of data access.

[5] Data like pictures and video clips from offshore operations and non-formalized text strings.

As denoted by the financial investments and public managerial statements, the big data in OMNIA was perceived as a valuable resource that mangers at EnergyCo could mobilize to solve not only specific problems but also cross-disciplinary issues. The Chief Digital Officer (CDO) elaborated on the particularities of big-data value:

> Today, we generate and analyze data for specific purposes, but we see significant untapped potential to utilize data across IT applications and organizational boundaries. We have drilling data, operational data, subsurface data, and supplier data, but we do not interpret it in an integrated way. Actions that involve the use of digital technology have normally been directed towards specific problems or opportunities in specific parts of our value chain. (int_doc_2)

The CDO and the Vice President of IT both viewed big data as a tool that could tear down inter- and intra-organizational boundaries that, prior to the investments, inhibited collaboration and caused problems. In this context, being too "specific" about the purpose of data and the problems it ought to solve would be reminiscent of the past.

4.1.2 The Dream is Everywhere

The rather abstract strategic ambitions of top management were not, in themselves, sufficient to perform in line with the big data dream. Hence, to move the organization towards the overarching goals of the digital strategy, EnergyCo constructed a digital roadmap (see Figure 1 in the Introductory Chapter). This inscription was to guide EnergyCo's divisions and departments towards a digital future, and ensure that all areas within the organization were progressing towards this ambition. The roadmap and the projects within it were monitored by the newly established Digital Center of Excellence. Funds were allocated as projects reached certain milestones, with the end-goal of implementing digital technologies in practice.

Motivated by the strategy, OMNIA, and the roadmap, numerous organizational actors engaged in developing proprietary visualization tools using technologies like Microsoft Power BI. This seemed to be exciting work and the optimism surrounding big data practices permeated the organization. A Planner Team Leader expressed enthusiasm about what access to more data and visualization tools might produce, and drew particular attention to the potential to increase both efficiency and safety:

> The use of data and data tools in general—everything that goes into the "digitalization" term—can increase both efficiency and safety. Definitively. We have enormous amounts of data we can use. (Planner Team Leader 2)

According to this leader, the prerequisite for increasing efficiency and safety through digital tools was enormous amounts of data. However, beyond having all of this data, the way in which it was stored mattered. Analyst 3 elaborated:

> Everything is in "the lake" [OMNIA], so now we can extract [all of these difference sources of data] at once to our tool. It is […] the future plainly and simply. […] This is the tool I have dreamed of for years—the tool everyone in the planning community has dreamed for years. (Analyst 3)

In other words, having "everything in the lake" enabled the development of tools of the future in which all of the data that had previously been available could be sourced and visualized, and in new ways. As such, OMNIA and flexible-visualization tools were technologies expected to make patterns in the data visible that could push the organization towards changing its practices. This was highlighted by Analyst 1 in relation to the lack of maintenance of certain types of safety-critical equipment:

> Why has this critical equipment not been fixed before? I think it might be because [these things] have not been visible enough. The data was available before as well, but it was not that visible. (Analyst 1)

This might also be why a Predictive Maintenance Analyst, in line with top management, claimed that the major source of value-creation potential in digitalization resided in the possibility to integrate data:

> The big value creation [happens] across data sources. The big difference from before […] is that we could not, within reasonable bounds, integrate our [own data sources] with the maintenance and ERP systems and, in a sense, see things in context. (Predictive Maintenance Analyst)

As such, the ability to see things in context was viewed as the value of big data in EnergyCo. The Predictive Maintenance Analyst continued:

> The largest stumbling block to digitalization […] is access to data—that it is made available in [OMNIA]. We want everything to be in OMNIA because then we can quickly make changes and switch systems later. We do not make a tailor-made system. (Predictive Maintenance Analyst)

The enthusiasm expressed by planners and analysts was also evident among the onshore and offshore operational units. For example, interviewees assumed that operations "would work better if you could collect data from here and there, and then compare and connect" (Operations Team Leader 1). In fact, offshore operational personnel highlighted the value of digitalization and technologies like big data in the "right" situations. The leader of an EnergyCo union elaborated:

> We have digitalization. We have monitoring [through sensors]. We have production optimization. We have many things that have been developed. All of these things have a positive effect. Do not get me wrong—I am not against the development within digitalization, but I am very preoccupied with [digitalization] being used in the right way. (Union Leader)

Initiatives like monitoring equipment and using that data for production optimization had a positive effect on the organization, according to the Union Leader. Digitalization, including the collection and storage of big data, was not at odds with the objectives of the offshore operations.

Given the statements from top management, analysts, planners, and operations representatives, it seems fair to argue that the big data dream of scientific management 2.0 has performative effects. In EnergyCo, a broad set of organizational actors added the following to the proposition: through access to vast amounts of data through OMNIA, the organization is able to rethink how management should be conducted. By collecting and storing excessive amounts of data in a disordered (Weinberger, 2007) technical infrastructure, the organization can manage an uncertain future.

4.2 Episode 2: Big Data Made Relevant

4.2.1 MATE: Optimization of Maintenance

The grounds for change were prepared in EnergyCo through investments in OMNIA, visualization technologies, and the development of and follow-up on the roadmap. Data was expected to serve as an input in visualizations that could aid in the more effective management of an uncertain future.

One justification for allocating funds to these types of investments was the belief in data's ability to enable cost cutting.

In the maintenance analysis unit, analysts worked to continually strike a balance between cost-efficiency and operational safety, which they referred to as "optimizing" maintenance practices. In the wake of the opportunities emanating from the digitalization strategy and OMNIA, managers higher up in the hierarchy exerted a push towards starting to "find some improvements [and] undertake some analyses" (Analyst 4):

> There was simultaneously a wish [from management] that we in maintenance management and analysis should try to visualize [data] and use the new tools that were introduced in recent years, meaning the automatization of data extraction and visualization. (Analyst 1)

This resulted in the establishment of the Digital Maintenance Visualisation and Analysis (DMVA) project, which was initiated to develop several new dashboards aimed at supporting the maintenance analysts in their daily work. The flagship of these dashboards was MATE, which was developed with the aim of optimizing maintenance operations:

> We need to try to find the optimal maintenance for equipment, where [operations] have an intersection between the lowest number of hours and the highest level of regularity.[6] We need to get as close as possible to that intersection. […] If we get the learning loop to work […] and continuously update MATE, we will move towards the optimum. (Planner Team Leader 3)

The origins of MATE can, at least in part, be traced back to problems in the analysis unit. Data and visualization tools had been used before, but they were largely manually constructed, and analyses were both challenging and time consuming:

> Before, I had access to the same data but had to source it manually and could only do analyses on single-plant level. Now, I can do the analysis on the concept level and compare plants. I used to spend a week on an analysis for one plant and it was not even on the concept level. Now, I can drill down to the concept level and

[6] "Regularity" refers to a concept within maintenance management theory that describes how well a system is capable of meeting predefined performance measures.

compare across plants. That is a major improvement. (Analyst 5, paraphrased from notes on interview about the use of MATE)

As there were "2.7 million pieces of equipment in [EnergyCo] distributed across 680 equipment categories [and] 590,000 pieces of equipment could not be assigned to any of these categories" (Analyst 4), the analysts welcomed the developments afforded by OMNIA and the visualization tools. The amounts of data were indeed "big" and difficult for the analysts to handle. An analyst involved in the MATE project from the beginning and in a leading role at the time of our study explained:

> We had the opportunity to transfer data to the cloud solution [OMNIA] and started to get tools that made it possible to handle larger amounts of data. We figured we wanted to develop a tool that help us put an X on the map. (Analyst 4)

The result was MATE and the "X on the map" were specific recommendations on where maintenance could be improved or, in other words, where a balance between safety and efficiency concerns could be struck more "optimally." Figure 3 illustrates the ways in which MATE reported maintenance data.

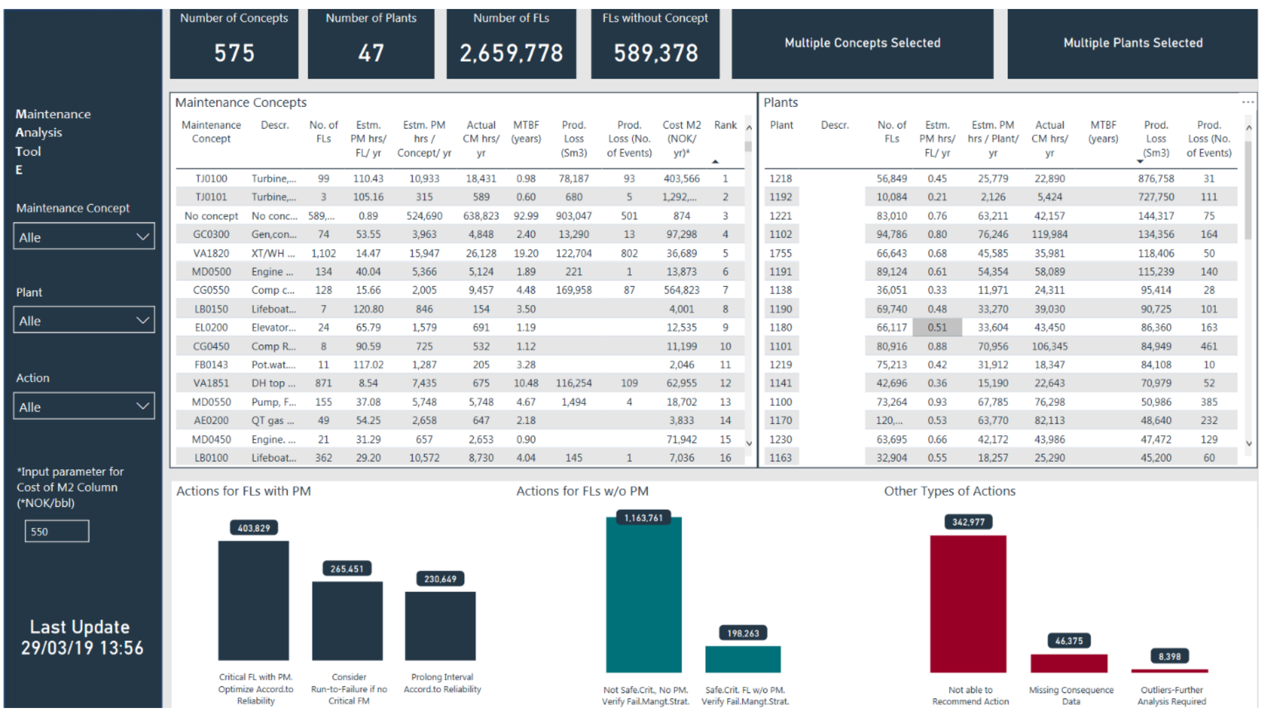

Figure 3 *Visualization of maintenance data in MATE*

Two spaces on the MATE dashboard in Figure 3 are important for understanding how costs were to be cut without compromising safety. First, the top-left table rank-ordered maintenance concepts by calculating what the analysts labelled "potential for improvement."[7] The calculation allowed analysts to allocate their time to what they considered to be high-potential equipment rather than equipment for which the trade-off between costs and safety was considered sub-optimal:

> We are sitting in an analysis unit with very limited resources. We are not more than 10-15 people. We cannot go through everything. […] So, we have used [MATE] to decide where to primarily focus our analysis efforts. (Analyst 4)

Second, the histograms at the bottom of the dashboard were detailed recommendations for actions to change the maintenance programs to realize the optimal trade-off. These categories were sorted automatically using a decision-tree algorithm that the analysts specifically developed for MATE. Although the algorithm was not "smart," it was based on "a mix of written and unwritten rules" (Analyst 4) about how to classify equipment in relation to subsequent maintenance actions. Hence, it categorized all equipment, and linked it to actions expected to lead to the optimization of maintenance in the short or long term. For example, the "Actions for FL with PM" category was intended to correct maintenance practices by changing the maintenance strategy for equipment contingent on evidence from a trail of test data indicating the equipment's technical condition. If equipment was not safety or production critical, a run-to-failure strategy was to be adopted. If the equipment was safety or production critical, but the data showed three or more successful functional tests, the maintenance interval was to be increased. Importantly, the algorithmic recommendations were not believed to always be fully accurate. Instead, they were intended to serve as "pointers" (Analyst 4) for the analysts in their work:

> Other things may influence the [maintenance] interval. In the end, there must always be an assessment by professionals about whether an interval needs to be reduced [or increased], so this is just a recommendation. (Analyst 1)

Through the table and action histograms, the analysts were able to see maintenance in a new light. More than just enabling the processing and visualization of large and diverse data volumes, new connections were established between data points that surprised even the analysts and took the

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[7] $PFI_i = \frac{Estm.\ PM\ hrs\ (yr)_i}{MTBF_i} \times Prod.\ Loss\ (Sm3)_i$, where i = maintenance concept.

analyses in new directions. Plants could be compared, work efforts could be allocated in a prioritized manner, and maintenance could be optimized. An “X” was put on the map by the technology, which was very difficult to locate before big data was made available through OMNIA.

4.2.2 The Facts on the Table

Through its calculations and visualizations, MATE was used to resolve a controversy: whether the intervals of maintenance should be predominantly decided on the basis of offshore workers’ years of experience, old structures, and instructions from the equipment suppliers, or in another, more cost-efficient way that still upheld the strict safety standards. “Trusting” the large amounts of available maintenance data in OMNIA seemed to be a reasonable alternative for some:

> We try to have a maintenance process in which we trust our own data and our own internal experience rather than just follow a recommendation from the supplier or rules that are [open for interpretation]. […] The analysts have developed tools that give us knowledge about the mechanisms of maintenance. […] As a leader, I believe that MATE, without doubt, gives me a holistic overview. (Planner Team Leader 4)

As the Operational Planner suggested, the maintenance organization already knew the problem—a satisfactory balance between costs and safety was not being achieved. In other words, the accounting systems that were supposed to contribute to effective cost management were not delivering. The big data contained in OMNIA seemed like a possible solution given its ostensive objective properties. MATE, as a tool that visualized that data, was expected to resolve the controversy because it presented the “facts”:

> [MATE] is designed to present the facts, objective data, and analyses that disarm empty rhetoric from the union or offshore workers. […] For example, if [MATE] shows that the mean time to failure for a valve is 150 years, then rhetoric about why we still need routine inspections and preventive maintenance should not trump facts. (Senior Analyst, from field notes during Interview 5)

This quote illustrates the ways in which the potential of MATE, through its mobilization of big data, was presented. It obviates the political and irrational regime that encapsulated the old managerial style. When asked whether this was a notable problem in EnergyCo, one analyst said:

> There have been so many discussions and so many protests regarding reducing [the maintenance programs] despite the data saying that we should. We hope that MATE and other digital tools will lead to decisions that are more fact based. (Analyst 9)

The analysts relied on MATE to solve the inherent problem of the maintenance organization by offering representations that "factually" challenged the development of the expanding maintenance programs and the associated costs. Drawing on big data from OMNIA, the analysts were able to disclose a new set of relations between data that allowed them to see things that had previously been "hidden." MATE was ostensibly both objective and innovative, and able to recast maintenance practices in a new light and settle controversy. Given the "facts" and new ideas about maintenance practices, addressing the problem of balancing costs and safety concerns seemed to be within reach for the organization.

4.3 Episode 3: The Dream Faces Reality

The organizational divide between onshore and offshore personnel, the critique of the validity of data underlying the analyses, and the limitations of representations to account for "the whole picture" stifled MATE's impact. The hope that big data visualizations in MATE would produce "facts" and address the tensions between safety and cost cutting was not fulfilled, leaving some analysts frustrated:

> Even with facts on the table, there are massive protests against reducing [maintenance programs]. (Analysts 9)

Notably, "facts" meant different things to different people in EnergyCo:

> Most of them [the analysts] have barely set foot on a platform. […] Their arguments are not based on facts. They are based on subjective opinions, unfortunately. (Offshore Electrician)

To operations, what was factual went beyond the data that was collected and stored in OMNIA and visualized in tools like MATE. Therefore, primarily basing changes in maintenance on analyses was viewed as potentially dangerous. Moreover, as the operations routines for reporting were questionable, even the data that the analysts considered factual could be critiqued:

> We also make mistakes. Often, we find small faults, but we do not bother to enter the fact that we fixed them into the system. Clearly, you can go for 10 years without seeing any faults [registered in OMNIA and detected in the analyses] and say "we do not need to do this maintenance anymore." […] The problem is that the picture does not match reality because we are too sloppy. (Offshore Electrician)

Due to the apparent blind spots in OMNIA, the experience-based knowledge that the offshore operations had accumulated through years of executing maintenance work was perceived as a necessary complement. In an echo of the Offshore Electrician, a Union Leader highlighted that failure to acknowledge this could result in a faulty representation of local realities:

> There are lots and lots and lots of holes [in OMNIA]. We have several examples of cases in which we cannot acknowledge the analysts' analyses. They show us analyses based on extracts from [the EPR] system, for example, and they do not fit with reality at all. If, in addition, you do not listen to the people [with knowledge about the equipment and how it should be maintained], you get a strange result. (Union Leader)

An Operations Manager elaborated:

> A typical problem with undertaking analyses when you do not have [specific competence on maintenance execution] is that you become an Excel expert, but you miss out on the essence. [You fail to recognize subtle details] and that is why an analysis always should be a combination of analytical and vocational competence. That is my opinion. (Operations Planner 3)

In other words, big data and the analyses based on it need to be complemented by people with maintenance competence. Otherwise subtle details might be overlooked and adjustments could be made that could negatively affect safety. The holes in big data and tools like MATE must be filled in by competent people.

Adding to the argument that the data did not represent the facts due to questionable reporting practices and resulting "holes" in the databases was a critique of the underlying cost-cutting ambition:

> The point is that [EnergyCo] targets cost cuts […], but then you are really at odds with the entire point of [safety assessments]. (Offshore Electrician)

Earlier experiences had illustrated to operations that cost reductions often equaled downsizing. However, as the number of people handling maintenance fell, some felt operations became riskier. The Union Leader voiced a critique along these lines:

> I get it—the firm will always aim to get costs lower, but there is no understanding [of our position]. We all want the best for the firm, but we have different standpoints, different experiences, and different views on the right course of action. […] I believe it is really important to have people [on the platforms]. (Union Leader)

The critiques, questions, and concerns raised by operations about MATE's ambition to reconcile considerations of safety and efficiency suggested that not everyone was convinced that this was possible, at least not in the way that the analysts suggested. According to the Union Leader, MATE did not appear to be the "right" way to digitalize. Consequently, concerns were voiced. However, this was not a critique of digitalization per se, as a statement from the Offshore Electrician, already presented at the beginning of this article, illustrated:

> This is really misuse of digitalization because digitalization and automation are very good. You input parameters to get an output. However, when you input the wrong parameters or you want a certain result, and then do some magic on the input data to get the output you want, then it becomes dangerous. (Offshore Electrician)

Here, the Offshore Electrician echoed a belief in digital technology as having the potential to be beneficial, but at the same time he criticized the analysts for making only certain parts of the picture relevant. As such, being critical of MATE was not the same as being critical of digitalization and big-data practices in general.

We now turn to a concluding discussion in which we draw on the findings from our three episodes to discuss the relationship between big data and accounting.

5. Concluding Discussion

This article aimed to investigate the relationship between big data and accounting by asking the following question: *How is the performativity of Big data influencing or influenced by accounting?*

To answer these questions, we conducted a longitudinal case study of maintenance processes in EnergyCo, which mobilized big data and visualization technologies to “optimize” such processes.

The theoretical backdrop of our study is that big data—through its proposition about the inherent value of data and, hence, practices of collecting and storing it for present and future use—produces a dream of scientific management 2.0. In this approach to management, human and non-human actors conjointly manage scientifically and adaptively at the same time. As such, this managerial approach is well suited for facing an essentially unknowable future (Schwarzkopf, 2020). Importantly, as big data is a philosophy of no philosophy (Berry, 2011), it prides itself on being “irrelevant” and perfectly adaptable to any context at any time. In other words, according to the big data philosophy, managerial knowledge should emerge inductively, not through the application of extant knowledge structures to the data. As such, the big data dream of scientific management 2.0 presents a challenge for accounting given its theoretically deduced objectives of producing relevant data for preconceived user groups.

In the following, we elaborate on two findings from our study of the MATE initiative in EnergyCo that help answer the research question. Our first finding that the rationale behind big data was present and accepted everywhere and by everyone indicates that the big data dream aligns with a common denominator not only in EnergyCo but also in societal discourse. In relation to accounting and big data, this finding suggests that actors accept big data’s particular problematization of accounting practices. This feeds into our second finding that the accounting visualizations constructed by actors in the maintenance operations and elsewhere to operationalize the big data dream were negatively received by certain actor groups. When big data is made relevant by a certain group of actors, they imbue the data with their own rationales and, consequently, the dream of scientific and adaptable management evaporates. Somewhat paradoxically, accounting visualizations are needed to move towards the dream, but they also make it break down.

By interpreting these finding through the lens of performativity, we can make two additional observations. First, the dream had a performative effect on EnergyCo, as it shaped the organization’s materiality and mentality. The dream found “practical instantiations” (Leonardi, 2010, p. 5), which were predominantly tied up in the digital strategy, the digital roadmap, and OMNIA. These shaped conceptions of what work in EnergyCo entailed. This work was inevitably enmeshed in the digital and in areas where big data played an important role in achieving the organization's overarching strategic ambitions. As indicated by the CDO and members of the wider organization, management in EnergyCo was no longer reduced to "specific purposes [or] problems" but should be "integrated." Hence, the discourse connected to the big data dream of scientific management 2.0 was a type of performative utterance (Austin, 1962) that constituted the local social world of EnergyCo in its name.

A second observation is that the agency behind the dream was distributed. There was no single sovereign behind the utterances of the big data dream and the constitution of the social was a continuous process. Its propositions were voiced and re-voiced by a highly distributed network of human and non-human actors (Latour, 1987), and the effects of the utterances were perlocutionary (Butler, 2010). For example, the discourse linked to the big data dream had a material effect on EnergyCo by producing the OMNIA data repository, and OMNIA became an actor itself, playing a part in the further constitution of the world. Through its non-relational properties and enabling of "seamless" (VP of IT) access to "everything" (i.e., "all" data; Predictive Maintenance Analyst), OMNIA allowed for continuous re-evaluation of relevance. As highlighted by MacKenzie (2006), the material plays an important role in performativity.

In relation to accounting, the visualizations that were produced in order to harness the potential of OMNIA also became actors themselves. MATE, the accounting visualization investigated in this article, indicated that big data should serve the goal of optimization in maintenance and it made a subset of data from OMNIA visible to attain this goal. In this way, MATE's voice as well as those of the analysts were a challenge to other voices (e.g., OMNIA's and operations') and, in fact, hindered the big data dream of changing maintenance practices. Notably, this was not because these actors were dissenters who opposed the dream, but because their actions were at odds with one of its central propositions: data should not be approached with a priori ideas about what is relevant and for whom it is relevant. When big data is imbued with relevance, negative reactions are likely, as this also links politics and ambitions to the ostensibly objective and pure. Accounting visualizations become political statements about what constitutes the correct interpretation of data, statements that by some are conceived as a "misuse of digitalization" (Offshore Electrician). This case shows how accounting visualizations are closely linked to the performativity of the big data dream, a finding that corroborates earlier accounting research on the link between "programs" and "technologies" (Miller & Rose, 1990; Robson, 1994). The analysts, MATE, and other human and non-human actors made up the conditions upon which the big data dream could be performative (Butler, 2010).

Through our findings and analysis, we make two contributions to the literature on accounting and big data. First, the big data dream of scientific management 2.0 offers an opportunity for the repurposing of accounts. When more data was made available in OMNIA, more accounting visualizations were produced for management (as per Ronzani & Gatzweiler, 2021). These visualizations were not constructed based on notions from explicit accounting knowledge but were informed by a variety of organizational actors' interpretations of how data should be used to achieve goals like cost-efficiency. As such, accounting journeys into novel locations and takes on a variety of formats, as "hybrid" accountants (Kurunmäki, 2004; Miller et al., 2008) make accounting their own concern. By intertwining with big data, accounting can seemingly more easily be put where it was not (Hopwood, 1992). Hence, accounting visualizations do not merely supplement traditional accounting numbers to enhance the accuracy of measurements, predictions, and human judgements (Appelbaum et al., 2017; Vasarhelyi et al., 2015; Warren et al., 2015). They also offer a critique of the usefulness of such traditional accounting numbers in relation to things like cutting costs.

Second, our case highlights that accounting and big data rest on different philosophical underpinnings that can clash in action. When humans operationalize big data in practice, they must make conscious choices about relevancy, which makes the dream of scientific management 2.0 crumble. Accounting is always connected to a particular ambition (Kaplan & Johnson, 1987; Power, 2010; Young, 2006), which may or may not conflict with other ambitions. In the big-data context, the political nature of accounting is highlighted in that it contrasts starkly with an ideally post-political technology (Saifer & Dacin, 2021). In settings where there are already strong opposing rationales, as in EnergyCo's maintenance operations, this contrast is further exacerbated, as one group of actors seems to hijack the objective for its own cause. In EnergyCo, this was evident in how MATE upset certain members of operations, leading them to categorize the initiative as a "misuse of digitalization" (Offshore Electrician). The case highlights how accounting, in certain circumstances, limits the performative power of big data because it is at odds with the ideal of "inexhaustibility" (Arnaboldi et al., 2017, p. 765).

As such, our analysis provides empirical evidence in response to conceptual claims in the literature on accounting and big data. We believe the continued repurposing of accounts in the form of new visualizations will continue, as there is a need to make sense of increasingly big datasets. However, these visualizations inevitably imbue data with some form of relevance. In other words, they are at odds with the central propositions of the big data dream of scientific management 2.0 and, thus, have the potential to prevent the reification of the dream in practice. How accounting visualizations are constructed, which actors are involved, and where construction occurs matter for the performativity of the big data dream. Future research could further investigate this claim by, for example, studying big data in settings other than industrial organizations with longstanding political tensions like EnergyCo. Nevertheless, our case provides empirical evidence of the paradox of the digital revolution (Quattrone, 2016), and shows that it both produces a strong belief in the possibility of arriving at rational management, and simultaneously augments uncertainty and reifies existing distances (Quattrone & Hopper, 2005).

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7. Appendix

Table 3 *Interviews*

#	Role	Date		Round	hh:mm	Recorded
1	Senior Analyst	13/03/19		1	02:00	N
2	Financial Controller 1	20/03/19		1	00:56	Y
3	External Maintenance Consultants	09/04/19		1	02:00	N
4	Senior Engineer 1 and Safety Representative	11/04/19		1	01:00	N
5	Senior Analyst, Analysts Team Leader and Analyst 1	11/04/19		1	01:30	N
6	Operations Planner 1	12/04/19		1	00:50	Y
7	Operations Planner 2	25/04/19		1	00:53	Y
8	Senior Engineer 1	30/04/19		1	01:00	N
	Total of eight interviews in Round 1					
9	Analyst 1	14/10/19		2	01:00	N
10	Analyst 2	16/10/19		2	01:05	Y
11	Data Governance Manager	16/10/19		2	01:00	N
12	Analyst 3	16/10/19		2	00:55	Y
13	Analyst 4	17/10/19		2	00:53	Y
14	Senior Performance Analyst 1	21/10/19		2	01:45	N
15	Analyst 5	22/10/19		2	01:00	N
16	Analyst 6	23/10/19		2	01:16	Y
17	Analyst 7	23/10/19		2	01:20	N
18	Analyst 8	23/10/19		2	01:04	Y
19	Analyst 9	24/10/19		2	00:58	Y
20	Analysts Team Leader	25/10/19		2	01:00	N
21	Planner Team Leader 1	28/10/19		2	00:39	Y
22	Planners Team Leader 2	29/10/19		2	00:41	Y
23	Integrated Operations Center Leader	30/10/19		2	00:45	N
24	Operations Team Leader 1	31/10/19		2	00:56	Y
	Total of 16 interviews in Round 2					
25	Analysts Team Leader	14/02/20		3	01:38	Y

26	Planner Team Leader 3	11/06/20	3	00:43	Y
27	Operations Planner 3	17/06/20	3	00:37	Y
28	Planner Team Leader 4	18/06/20	3	00:58	Y
29	Operations Team Leader 2	13/08/20	3	01:03	Y
30	Union Leader	21/08/20	3	00:56	Y
31	Operations Electrician	31/08/20	3	01:19	Y
32	Operations Team Leader 3	04/09/20	3	01:03	Y
33	Analysts Team Leader	11/09/20	3	00:30	N
34	Predictive Maintenance Team Leader	12/01/21	3	01:00	Y
35	Predictive Maintenance Analyst	12/01/21	3	00:56	Y
36	Analyst 4	14/01/21	3	00:57	Y
37	Analyst 10	14/01/21	3	01:01	Y
38	Analysts Team Leader	28/01/21	3	00:35	Y
39	Analyst 4	22/09/21	3	00:15	Y
40	Safety Engineer	29/09/21	3	01:25	Y
	Total of 16 interviews in Round 3				

Table 4 *Selection of retrieved documents and media*

#	Code	Media type	Content description	Retrieved
1	int_doc_1	Document	Article about the launch of digital strategy with interviews of CEO and COO	26/11/2020
2	int_doc_2	Document	Article about how digitalization was changing EnergyCo with interviews of two employees and CDO	23/04/2021
3	int_doc_3	Document	Presentation slides about EnergyCo's technology strategy	26/11/2020
4	ext_doc_1	Document	Norwegian government's national artificial intelligence strategy	26/11/2020
5	int_doc_4	Document	Presentation slides about OMNIA and new digital opportunities for energy production	06/11/2020
6	ext_vid_1	Video clip	Public webinar held by the Norwegian government about digital transformation of society as an effect of the COVID-19 pandemic	08/01/2021
7	ext_doc_2	Document	Newspaper article about presentation of budgetary allocations for digitalization in Norway	07/10/2020
8	ext_vid_2	Video clip	Digital networking event about digitalization of Innlandet region in Norway	28/01/2021
9	ext_doc_3	Document	Factsheet/infographic on the Digital Europe Programme	28/01/2021
10	int_doc_5	Document	Article about purpose of OMNIA by EnergyCo's CIO	23/04/2021
11	int_doc_6	Document	Article about the launch of the IOC center with interviews of top management	04/05/2021
12	int_doc_7	Document	EnergyCo corporate presentation	20/05/2021
…	…	…	…	…

Chapter 2

Concealed Pathways: How the Visibility of Links in a System of Inscriptions is Influenced

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Abstract

Contemporary organizations are managed through systems of interlinked inscriptions. Research has shown that the materiality of the links that bind such systems together, especially their visibility, is central for the systems' functionalities. However, less attention has been devoted to investigating how the visibility of links is influenced. I conduct a longitudinal case study of the maintenance operation in EnergyCo (a pseudonym), where a system of interlinked inscriptions was crafted to balance concerns about financial performance and safety risk. The analysis of the empirical material shows that the visibility of links is influenced by actors' capacity for specialized knowledge. I contribute to the extant literature by showing that the materiality of links in systems of inscriptions must sometimes be supplemented by social aspects, like actors' capacity for specialized knowledge. The implication for research is that the analysis of accounting inscriptions should not be restricted to individual inscriptions but should devote equal attention to understanding the properties of links that bind them together in systems of management and the aspects that influence those links.

Keywords: Inscriptions, visual pathways, specialized knowledge, digitalization, case study

1. Introduction

Contemporary organizations rely on documents, like reports, lists, tables, and graphs, to realize their objectives (Jordan et al., 2018; Qu & Cooper, 2011; Quattrone, 2009;). However, as single documents rarely capture all necessary information (Jordan & Messner, 2012), organizations usually link an array of documents together into a functional, but mutable, system that aims to provide a more 'complete' information base for management (Martinez & Cooper, 2019). This practice of linking documents for management has recently been boosted by technological developments within data capture and storage. As more data becomes available, new documents and links between documents tend to be created in order to disclose alternative approaches to management (boyd & Crawford, 2012; Constantiou & Kallinikos, 2015a).

The visual "format and furniture" (Pollock & D'Adderio, 2012, p. 568) of singular documents for management has been investigated in a growing body of literature on inscriptions (Latour, 1987; Robson, 1992). Recent studies in this stream have aimed to analyze how the sociomaterial and visual properties of inscriptions play a role in shaping organizational realities (see, e.g., Jordan et al., 2018; Qu & Cooper, 2011; Quattrone, 2009;). However, most of the extant literature has studied the role of one inscription, such as the virtual ledger (Quattrone, 2009), the Balanced Scorecard (Qu & Cooper, 2011), or the risk matrix (Jordan et al., 2018).

Although these studies offer important contributions, they do not explicitly foreground inscriptions as part of an interlinked system. Recently, however, researchers have alluded to the importance of theorizing such systems, especially the links that bind inscriptions together (Martinez & Cooper, 2019). In this regard, links are theorized as "visual pathways" (Martinez & Cooper, 2019, p. 2)—materially inscribed guides and instructions about how to engage with the system.. Although these authors argue that the visual properties of links are "central for [the] calculative functionalities" (Martinez & Cooper, 2019, p. 2) of systems of inscriptions, we know little about the sociomaterial processes that condition and influence the visibility of links. Hence, in this article, I ask *how are the visual properties of links influenced?*

To address this research question, I conducted a longitudinal case study of an industrial energy company's (henceforth EnergyCo) efforts to link different documents into a system focused on balancing the tradeoff between financial performance and safety risks in its maintenance operations. The realization of this objective required the forging of links among multiple documents. In 2017, the organization began investing substantially in digital technologies, which engendered an increased reliance on data and tools for analysis and visualization, and afforded the creation of new documents and new links between them.

I contribute to the literature on inscriptions (e.g., Martinez & Cooper, 2019; Robson, 1992) by highlighting how a certain property of sociomaterial pathways—visibility—is influenced by certain social aspects. Specifically, I show that one aspect requiring attention if we are to understand the visibility of links is actors' capacity for specialized knowledge. Moreover, the findings indicate that although studies of singular inscriptions provide valuable insights, we should pay equal attention to understanding the properties of the links that bind them together in systems of management and the factors that influence them. While we know that the material properties of visual pathways matter for users' abilities to engage with systems of interlinked inscriptions (Martinez & Cooper, 2019), I show that specialized knowledge can contribute to the visibility or concealment of material pathways.

The remainder of this article is organized as follows. In the next section, I elaborate on the role of accounting inscriptions in establishing linkages, both individually and as a part of interlinked workspaces. In Section 3, I introduce the empirical site—EnergyCo—and outline the processes of data collection and analysis. In Section 5, I present the empirical findings, which show the details of the system of interlinked inscriptions that was constructed to balance the tradeoff between financial performance and safety in EnergyCo's maintenance operations. This section pays particular attention to the links among inscriptions. Finally, Section 6 offers a concluding discussion that connects the findings to the extant literature and presents this article's contributions.

2. Theoretical Foundations: Visibility of Links Among Accounting Inscriptions

Accounting has been shown to play a key role in linking distinct actors, ambitions, and arenas (Miller & Power, 2013). For example, governmental ambitions, emerging technological opportunities, national economies, and ideas of scientific rigor have been linked through accounting to shape society and organizations, at least temporally (Burchell, Clubb, & Hopwood, 1985; Miller & O'Leary, 2007; Robson, 1994). Linking also occurs within organizations (Jordan et al., 2018; Qu & Cooper, 2011; Quattrone, 2009), as accounting has the potential to bring people (and things) together through its ambiguous yet specific characteristics.

In his seminal paper, Robson (1992) connects accounting to the notion of inscriptions (Latour, 1987) and, on that basis, theorizes that accounting can link things. He argues that accounting is a particularly useful epistemological tool that enables action at a distance. In other words, accounting is a powerful medium—or inscription—that effectively translates what is "out there" to "here" because it relies on numbers. The quantitative is particularly mobile, stable, and combinable, making it possible to "[bring] together and mak[e] the same" (Robson, 1992, p. 701) diverse things (e.g., buildings, organizational processes, stock). Subsequently, calculations can be conducted on accounting numbers to act on distant contexts.

Drawing on the notion of accounting as inscription, Quattrone (2009) investigates the conditions that allow accounting representations to be successfully disseminated. These representations succeed because they are rhetorical machines consisting of a particular method and orthopraxis, which pass through a medium with a certain visual appeal. Therefore, to understand the diffusion of accounting, it is important to understand both its practice and its form. Quattrone (2009) argues that inscriptions can be conceptualized as "performable space" (p. 109)—a visual order making up a frame within which people can perform accounting practice. These spaces do more than merely convey knowledge. They can bring together various organizational actors as they attempt to fill in what is missing from accounting.

In their study of inscription building, Qu and Cooper (2011) examine how a Balanced Scorecard emerges as a detailed process involving a range of people and devices. In particular, they show how a group of consultants mobilizes certain inscriptions (numerical and non-numerical) to promote a Balanced Scorecard in the organization, but that they eventually fail to convince their client. This finding highlights the fragility of accounting inscriptions and shows that even though they are described as powerful tools that can affect actor's behavior, their effects are not always predictable. Moreover, the authors highlight that "not all inscriptions are equally convincing" (Qu & Cooper, 2011, p. 344), which suggests that the form of inscription plays a role in the success or failure of accounting in linking things together (e.g., consultants and clients).

In a similar fashion, Jordan et al. (2018) shows that risk matrices have visual appeal, and that they contribute to linking up specialized and everyday discourses as well as programmatic ideas in society and localized practices. Through collective symbols (Link, 2010), like color codes (e.g., green, yellow, red), risk matrices can be quickly understood and can convey specialized knowledge to non-experts. As a result, they have become a popular accounting format. Through their aesthetic appeal, rather than their ability to accurately represent reality through numbers, risk matrices "engage a variety of users" (Jordan et al., 2018, p. 52).

These studies collectively draw attention to the idea that the "format and furniture" (Pollock & D'Adderio, 2012, p. 568) of accounting inscriptions matters for linking. By paying attention to the visual order (Quattrone, 2009) and aesthetic appeal (Jordan et al., 2018) of accounting, these studies elaborate on our understanding of how inscriptions can link things together, although the outcomes can be unpredictable (Qu & Cooper. 2011).

However, large contemporary organizations are rarely managed through isolated inscriptions. Instead, they are managed through interlinked inscriptions that collectively make up systems of management. Although the above-mentioned research acknowledges that accounting can link things, it does not pay particular attention to the links and their properties. Martinez and Cooper (2019) provide a development in this direction by investigating how a loose network of funding agencies and non-governmental organizations (NGOs) engages with systems of inscriptions. Like previous studies, these authors highlight the importance of visual features. However, they also show that the visual is important for connecting various individual performance systems into a whole. Actors are able to engage with this "workspace" (Martinez & Cooper, 2019, p. 3) of interlinked inscriptions because of materially inscribed guides and instructions, or visual pathways. These pathways allow for patchwork-type interventions, meaning that the inscriptions are programmed to "act on one another to 'fix' an unexpected and perceived shortcoming" (Martinez & Cooper, 2019, p. 2). Hence, the visual and material properties of pathways are central for users' abilities to engage with the calculative system, and for the system to work. They contain "scripts"—that is, "rules and procedures" (D'Adderio, 2008, p. 773)—as well as material features like "cells," "linguistic labels," and "orders" (Martinez & Cooper, 2019, p. 17) that enable users to perform the workspace. Like singular inscriptions, the authors argue that the material matters in relation to the ability of the workspace to foster engagement, but they also highlight the materiality of links and a certain property of materiality—visibility.

Although the visibility of pathways is arguably "central" (Martinez & Cooper, 2019, p. 2) for actors' engagement with a system of inscriptions, we do not know much about the sociomaterial processes through which the visibility of links is influenced. In other words, certain conditions may influence the visibility of links and, as a result, foster different types of engagement. For example, in contemporary organizations investing in recent technologies for (big) data capture and storage, the visibility of links might be conditioned on organizational actors' knowledge about information technology.

I now turn to an elaboration of the empirical site, and its system of inscriptions for balancing the tradeoff between financial performance and safety risks in its maintenance operations.

3. Research Methods

A longitudinal case study design is relevant for empirically investigating how the properties of inscription links are shaped. Case studies are particularly useful for studying technology in practice as well as the networks in which they are embedded (Ahrens & Chapman, 2006). Proximity to the empirical setting was gained primarily through 40 semi-structured interviews and a three-week fieldwork period on site in addition to an analysis of documents.

3.1 Case Description

The case organization is EnergyCo, a global energy company that mainly operated in the petroleum sector. The company's largest and most mature business area operated on the Norwegian Continental Shelf ("offshore production") at sites characterized by varying production capacities and ages. At the time of the study, operations employed the majority of company's workforce (more than 21,000 people) and contributed about three-quarters of total revenue.

The Norwegian state was a majority owner of EnergyCo, with 67% of the shares. Hence, the social democratic philosophy underpinning Norwegian society was reflected in the state's expectations of the organization. For instance, even though an internal hierarchy was in place, employees were empowered to take responsibility and not shy away from accountability.

The firm divided its workforce between onshore and offshore personnel, which were considered equally important for organizational performance. The onshore organization provided a range of services to the offshore organization, including finance and control, analyses, and planning. The onshore workforce was dominated by engineers and was highly educated relative to the offshore organization. The offshore workforce mainly included vocationally educated technicians, many of whom had extensive experience. Efforts to ensure the offshore and onshore communities could work together towards achieving strategic ambitions faced numerous challenges, as these two communities inhabited seemingly different worlds (Mennicken, 2008) that were not easily connected.

Although the petroleum industry has historically been highly profitable, it is vulnerable to fluctuations in the oil price. Therefore, striking a balance between cost-efficiency and safety concerns is important, but not always achieved. In 2017, EnergyCo launched a digital strategy, driven in part by the belief that big data would enable it to more efficiently achieve this the tradeoff. As a result, more than 3,000 legacy systems were transferred to a new, non-relational data repository named OMNIA ("everything" in Latin), with the goal of finding new ways to create value.

To narrow the scope of the investigation, I chose the maintenance operations as my empirical focal point. These operations were particularly interesting because they incurred substantial costs and risks (at least for the offshore personnel), two aspects that needed to be balanced. In the wake of the digital strategy, MATE (Maintenance Analysis Tool EnergyCo) was developed to source data from OMNIA in order to achieve maintenance-optimization objectives through analyses of "objective" data. However, MATE was part of a system of inscriptions, all of which were produced with the objective of realizing an effective tradeoff between financial performance and safety risks.

3.2 Data Collection and Analysis

A research project on digitalization in EnergyCo provided access to the empirical site. The project was a continuation of a long-standing relationship between the author's institution and the company. As such, EnergyCo was already accustomed and welcoming to the presence of researchers. Therefore, few restrictions were placed on the research process. Through an initial meeting with the Chief Digital Officer (CDO) and the Chief Analysts of the Finance and Control Department, the maintenance process was identified as a suitable empirical setting, as the maintenance operations were already in the process of utilizing data and technology for analysis and visualization in order to make improvements. After data collection included 40 semi-structured interviews in three separate rounds, a three-week fieldwork period in an analysis unit in EnergyCo's maintenance operations, and analysis of numerous internal and external documents related to different aspects of the organization. The data collection period stretched from March 2019 to September 2021.

However, the data-collection process was not linear. The first round of interviews, which took place from March to April 2019, included eight exploratory interviews of representatives of the maintenance operation. Questions revolved around identifying digitalization projects within maintenance for in-depth study. The interviews directed the project to the Digital Maintenance Visualization and Analysis (DMVA) project within the maintenance operations. Contact with the leader of the DMVA project was established though our interviewees and dates for the three-week fieldwork period were agreed.

The second round of interviews took place during the fieldwork period in October 2019. Sixteen additional interviews with informants from the DMVA project and from the wider maintenance operations were conducted during this period. Questions in these interviews focused on the design and use of digital technologies for the informants' work. In addition, observations were conducted to broaden the understanding of digitalization in maintenance work as well as its contribution to achieving a balance between financial performance and safety risks.

The third round of interviews stretched from November 2019 to September 2021. These interviews were conducted to gather supplementary data that was important for theorization. As the collected material was theorized, certain holes were discovered and filled through additional interviews. For example, I felt the need to collect additional data on the offshore operational perspective on digitalization, as previous interviews indicated that the use and perception of technologies differed from those of the onshore actors.

Finally, throughout all data-collection periods, but particularly during the fieldwork period, a substantial number of documents was collected and analyzed to triangulate data from the interviews and observations. The majority of these documents contained sensitive information and access was restricted to on-premise viewing. In these instances, relevant information was noted in a fieldwork journal. The majority of the interviews were recorded and transcribed. When interviewees felt that they could speak more freely without being recorded, I took notes during the entirety of the interview and wrote an extensive summary directly following interview completion. The data collection concluded in September 2021, at which point additional interviews in the third round seemingly only provided incrementally interesting points. The vast amount of material collected up to this point contained several interesting pathways that could be followed, including that of theorizing links in systems of inscriptions.

Data analysis occurred during and after data collection (Langley, 1999; Locke & Golden-Biddle, 1997) by recursively jumping between empirical material and theoretical conceptualizations. This enabled sensitization to potentially interesting theoretical phenomena over time (Timmermans & Tavory, 2012). I entered the field with only a set of abstract empirical and theoretical concepts like "digitalization," "big data," and "management control." Therefore, the interview protocol did not have a tight structure but was designed to allow the emic perspective of the informants to guide the investigation (Lukka & Modell, 2010). This was particularly important in the first round of interviews.

After completion of the first round, the interviews were transcribed and analyzed, with a focus on recurring themes in relation to digitalization and accounting practice. As mentioned above, this directed attention to the DMVA project and the digital accounting tools (e.g., MATE) being developed to improve the maintenance operations. The theoretical focus of this round of fieldwork and interviews was the design and use of the digital accounting tools as well as the factors that conditioned specific design choices and usage. I questioned designers about, for instance, design specifics, the purposes of tool development, intended users, and current users. Moreover, identified users were asked about things like the usefulness of tools in their work practice, how (or whether) the tools helped them achieve their key performance indicators (KPI), and their involvement in the design process. During the interviews, it became clear that digital accounting tools like MATE were not having the desired effects on maintenance practices. In other words, they had not "optimized" maintenance practices by balancing financial performance and safety risks.

After completion of round two, the empirical material was again analyzed, but more attention was paid to understanding why digital accounting tools were not successful in realizing their objectives. As such, an analytical model of the theorized actor groups in maintenance, the material devices they used to perform their work, and the relationship between these human and non-human actors was constructed. This model was tested against other researchers' interpretations and presented to certain informants for validation. During this analytical exercise, a system of interlinked documents started to emerge from the empirical material. For example, a certain calculation—the ABC indicator—could be traced across interviews of both operational and onshore staff, indicating that certain objects "glued" the maintenance process together. After conferring with the literature, this object and others like it were conceptualized as as inscriptions.

This analysis triggered the third round of interviews, which aimed to piece together the puzzle of this system of inscriptions. The focus shifted towards searching for a potential pathway linking objects like the ABC indicator and MATE together. After completion of the fortieth interview, a pathway was identified, thereby creating a natural end to data collection. The conjoined process of data collection and analysis had led to the unearthing of a system of interlinked inscriptions with the goal of balancing financial performance and safety risks.

I now turn to a presentation of the findings.

4. Empirical Findings

4.1 A Tale of Two Goals: Financial Performance and Safety Risk

EnergyCo continually worked to balance financial performance and safety risk. The extraction of oil from the Arctic North Sea requires careful attention to safety but entails significant costs, as offshore operations face a set of complexities that are not as present in similar onshore environments (Necci et al., 2019).

In 2014, a significant drop in the oil price led EnergyCo to drastically rethink its approach to its business. A large-scale cost cutting program was initiated, which included the renegotiation or termination of third-party contracts and ambitious plans for internal cost cuts though the adoption of a lean philosophy (Womack et al., 2007). This "reboot" sought to help employees and third-party suppliers adopt a mindset of continual improvement and, thus, make them aware of the materiality of costs in EnergyCo's operations. The days of waste were over.

After 2014, a shared understanding of the importance of cost-efficiency and its implications for EnergyCo's operational margins and stock price produced a general acknowledgement of the business side of the organization. For maintenance, this meant paying close attention to costs:

> This is, in fact, a hot-dog cart. Just like other [businesses], we have to manage our costs. (Planner Team Leader 3)

The safety risks in EnergyCo's offshore operation were not taken seriously in the company's early years, resulting in a range of incidents, including drownings, explosions, and helicopter crashes. However, safety had been moved front and center as a result of demands from the Norwegian state as majority owner and governmental supervisory bodies like the Petroleum Safety Authority

(PSA).[8] The corporate ambition, communicated to society at large as well as the capital markets, was clear: "Our vision is zero harm" (int_doc_10). An Operations Planner in the maintenance operation explained how strict attention to safety influenced her work:

> What is the most important thing to prioritize? For us, it is safety. Just attending to safety takes up a lot of our time. […] Each month, [we get] the results for the last month regarding how much safety-critical lag we have. We have a limit for how much we are allowed to have. If we have too much, which has recently been the case, we get a lot of attention from above: "What is this? Why is it like this? Why have you not…?" There is a lot of focus on that. (Operations Planner 1)

Both financial performance and safety risks were highly important to EnergyCo. Costs had to be managed if the "hot-dog cart" was to be profitable and attractive to its owners, the largest one being the Norwegian state. Moreover, safety could not be compromised, as that could lead to a loss of lives, negative effects on the company's legitimacy in Norwegian society, and the incurrence of fines and production shutdowns. EnergyCo continually worked towards successfully balancing the two and it relied on a system of interlinked inscriptions to do so.

4.2 A System of Interlinked Inscriptions for Balance in Maintenance

The system of interlinked inscriptions for balancing financial performance and safety risk in EnergyCo maintenance is illustrated in Figure 4.

[8] The PSA is authorized to determine parameters for the Norwegian petroleum sector through detailed regulations concerning safety and working conditions. It also conducts audits to ensure compliance with the regulations and has the authority to sanction breaches through measures like plant shutdowns and coercive fines (ext_doc_1).

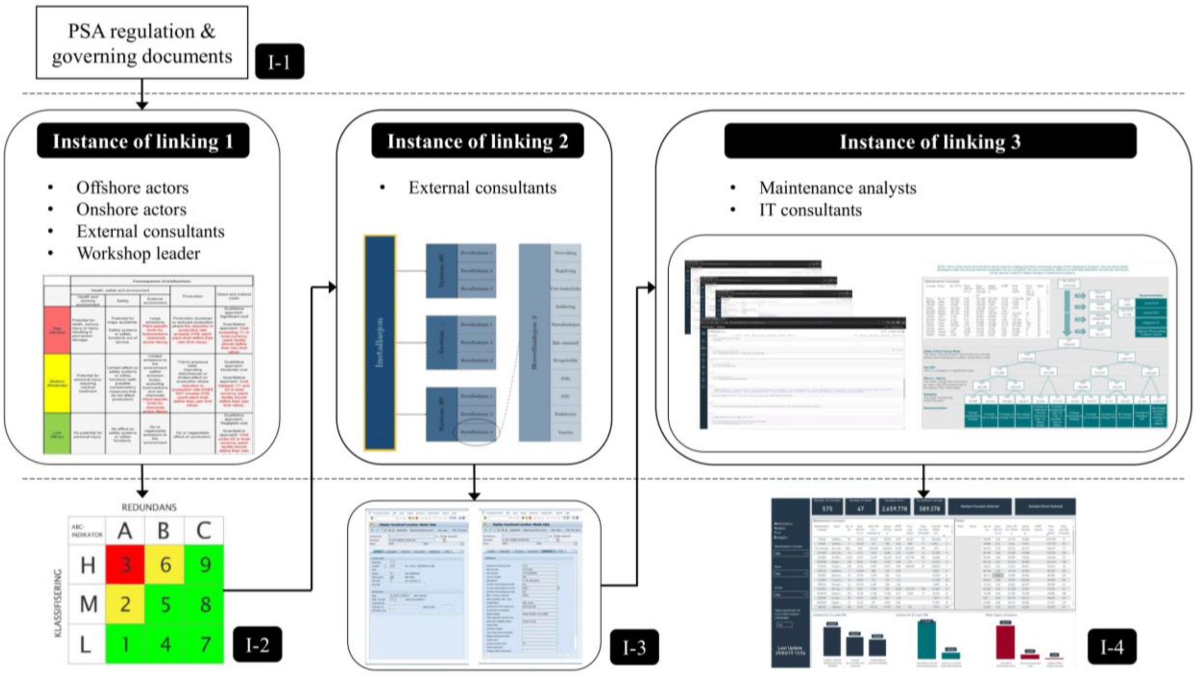

Figure 4 *System of interlinked inscriptions for balancing financial performance and safety risk in EnergyCo's maintenance operations*

If we move from the top left to the bottom right of Figure 4, we see that, during a workshop, governmental regulations (I-1) about equipment safety standards were translated into an accounting inscription—the ABC indicator (I-2)—indicating the risk of a particular equipment's breakdown for both financial performance and safety. This indicator was subsequentially added to tables (I-3) in the central database through customized software designed by external consultants. From there, equipment with certain ABC indicators (yellow and green) was automatically extracted and processed through code scripts, sourced into a decision-tree algorithm that sorted it into action categories, and visualized in the MATE dashboard (I-4). MATE then presented recommendations for changes that could be made in maintenance practices based on the subset of equipment (yellow and green) identified by the ABC indicator.

In the following sections, I present details on three separate but interconnected instances of linking: the workshop, the transfer to ERP tables, and the automated sourcing to MATE. These instances of linking held the system of inscriptions together.

4.2.1 Instance of Linking 1: The Workshop

Government regulation, which was enforced by the PSA, demanded that "all equipment must undergo a criticality assessment" (Analyst 4). In other words, all equipment had to be classified in relation to the safety risk associated with a breakdown:

> The platform-specific consequence analyses are unavoidable demands in Norwegian Standard 5814. All petroleum regulations include demands about this. (Operations Electrician)

The regulators primarily aimed to ensure safe working conditions for employees in the Norwegian industry. Although EnergyCo shared this motivation, it also needed to strike a functional balance between classifying equipment as safety critical or non-safety critical. If too much equipment was classified as safety critical, no space for action would be left to ensure cost-efficiency. The company's governing documents—internal interpretations of external regulations and specifications of how organizational practices should ensure compliance with those regulations—functioned as a guide for organizational actors attempting to achieve this balance in practice.

The method for classification institutionalized in EnergyCo's maintenance operations involved assigning all equipment a number from one to nine in the ABC matrix (see I-2 in Figure 5). Internally, this process was referred to as a *criticality assessment*. The number emanating from the criticality assessment was referred to as the "ABC indicator" and determined how critical the specific equipment was in case of function loss. It also established the maintenance strategy that should be assigned to it. For example, an ABC of 3 was the highest overall criticality classification. Equipment with this classification was assigned the highest priority in relation to maintenance. Such equipment was unlikely to be eligible for an extension of maintenance intervals. Equipment assigned ABC indicators of 1, 4, 5, 7, 8 or 9 was more likely to be eligible for interval extensions.

However, assigning a piece of equipment an overall ABC indicator was not trivial work. It usually occurred in workshops lasting one to two weeks. The scope of the workshops varied, but they all involved the classification of equipment at new installations or the reclassification of equipment at an installation after major modifications. In these workshops external consultants, onshore maintenance engineers, representatives of offshore installations, and a workshop leader would work together for long stretches of time to reach consensus about how all equipment was to be classified. Extensive alignment work was usually required from the workshop leader to get everyone on the same page:

> The first day is always very slow but we eventually reach a consensus. They then feel that they understand it and own the process. My job is to facilitate and steer them towards a belief that they have managed to reach this [understanding] themselves—that they have not just been told what to do. Then it becomes much easier. (Workshop Leader)

Practically speaking, the workshop leader reverted to his proprietary technique for reaching consensus. He always demonstrated an application of the methodology for criticality assessments, took time to listen to actors' "what if" questions, helped participants identify the goal of the workshop (i.e., the analysis of the consequences of equipment failure), and took the group "out [to] eat dinner together" (Workshop Leader) to induce a feeling of togetherness.

Consensus was considered important because all groups involved initially had different perspectives on how to ensure a successful tradeoff between financial performance and safety risk. The differences between the offshore and onshore groups were the most prominent. The onshore maintenance engineers generally believed that the tradeoff should be informed by risk assessments of the same equipment on other EnergyCo installations. In other words, they felt that best practices should influence a particular criticality assessment. This perspective was shaped, at least in part, by the engineers' knowledge about equipment and how it should function in general:

> [Onshore] experts on, for example, valves, junction boxes, and transformers highlight how we generally [should] do maintenance on this type of equipment. [They say] "grease every six months, do an inspection every fourth year," and so on. (Analyst 4)

However, the offshore representatives generally believed that local considerations had to influence risk assessments for particular equipment. That is, idiosyncratic local conditions could make best practices unsuitable. This perspective was rooted in the offshore representatives' knowledge and their extensive, situated experience with the equipment in its local setting. Such knowledge, for example, enabled them to identify situations in which the general maintenance recommendations should be bypassed:

> Thermography and splitting [of pipes] do not go together because you have a potential ignition source in an area where you are working on [equipment that channels] hydrocarbons. (Operations Planner 2)

However, after a few hours in a room together, and with the aid of the workshop leader, participants were generally able to reach a consensus and the actual classification work began. Everyone in the room was handed a more detailed ABC matrix on the consequence of equipment malfunctions (Figure 5, Instance of linking 1). The reason was that equipment could be critical in relation to different *consequence classes* of safety, production, and cost. In the workshop, the consequences of specific equipment's function loss for each consequence class were evaluated and assigned to the categories of high, medium, and low. A classification of high, for example, meant that breakdown of the equipment could have severe consequences like death, production shutdown, or significant costs. If equipment was classified as high in one of the consequence classes, it received an overall ABC indicator of 3, 6, or 9 depending on the evaluation of redundancy.

The redundancy classification entailed a check for the existence of surplus capacity due to the presence of multiple, parallel pieces of equipment that reduced the risk of function loss. In other words, if a backup for the focal equipment could immediately take over its functions in case of breakdown, there was redundancy. Redundancy was categorized as A (no backup), B (backup of one unit), or C (backup of two or more units). As equipment redundancy varied across platforms, the local offshore representatives were expected to take the lead in this classification activity during the workshop.

The workshops served as a link between the ambiguous rules and regulations and the ABC indicator. Through an amalgam of onshore and offshore actors, the mediating work of the workshop leader, the detailed ABC matrix outlining the classes of consequences in cases of equipment failure, and the expertise of external consultants, the regulations were linked to a matrix of discrete numbers.

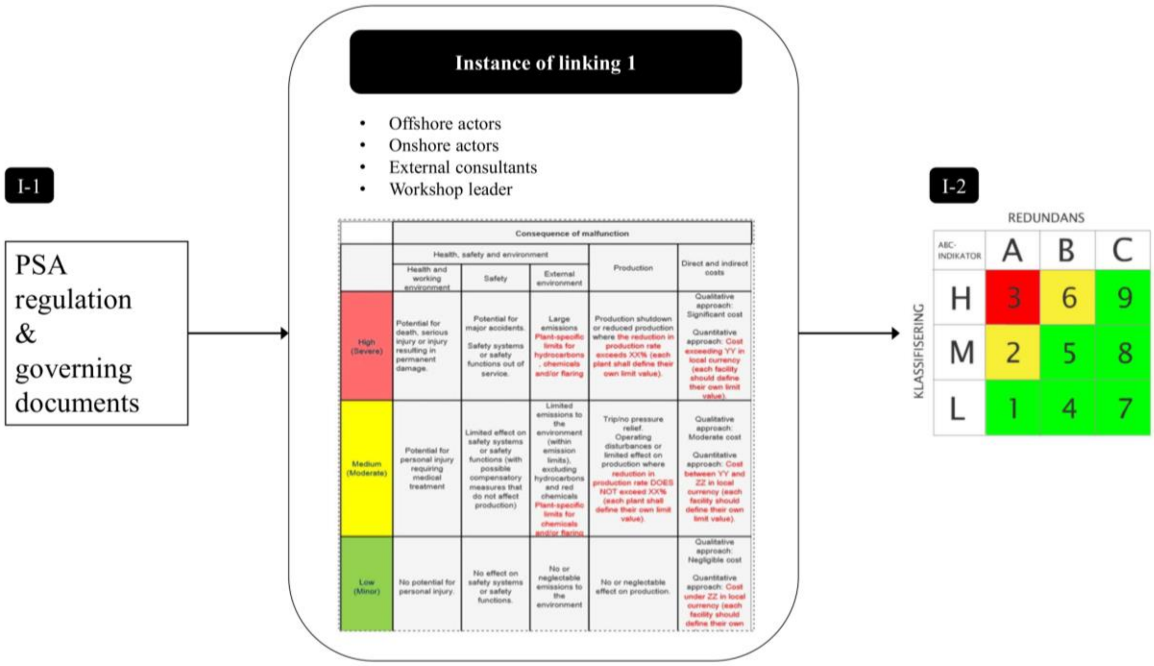

Figure 5 *First instance of linking in the EnergyCo system of interlinked inscriptions—shows how ambiguous external and internal regulations were linked to the ABC indicator through a workshop*

4.2.2 Instance of Linking 2: The Transfer to ERP Tables

At the completion of the workshop, the consensus from the workshop needed to be codified and structured. In this regard, EnergyCo relied on the expertise of a group of external consultants who specialized in consequence classification for equipment according to the PSA regulations. The consultancy firm had developed a set of guidelines in collaboration with EnergyCo to "ensure a uniform method [for consequence classification] in line with governing documents" (int_doc_1). This method conceptualized each EnergyCo platform as a four-level "functional hierarchy" (int_doc_1)—a set of interconnected systems that each had a subset of main functions and sub-functions. Furthermore, the method required all equipment to be "linked to the right part of the functional hierarchy" (int_doc_1). Only then could an ABC indicator be assigned to the equipment. Moreover, the consultancy firm designed a "tool for consequence classification" (int_doc_1) to be used when the output from the workshop (i.e., the assigned ABC indicators) was to be transferred to the organizational database.

[The ERP system] has no [criticality] classification module, but we have [a tool] where we make the classification and then load it into [the ERP system]. (Workshop Leader)

As EnergyCo relied on an external consultancy firm for its internal criticality assessments, there was a close connection between the two companies and even some “revolving door” cases. The Workshop Leader was an example of such a case:

I worked in [the external consultancy firm] with risk reliability and maintenance for ten years, and then I joined EnergyCo in April of last year. (Workshop Leader)

The consultants’ custom tool was crucial for linking the assigned ABC indicators to tables in the ERP system. Detailed consequence and redundancy classifications, and the resulting overall ABC indicator were loaded into tables in the ERP system via the custom tool (Figure 6, Instance of linking 2). As such, the use of the tool commenced during the workshop when the ABC indicator was to be formalized, but its main use was after the workshop’s completion. The external consultants took the lead in this part of the process, as they were the designers of the custom tool.

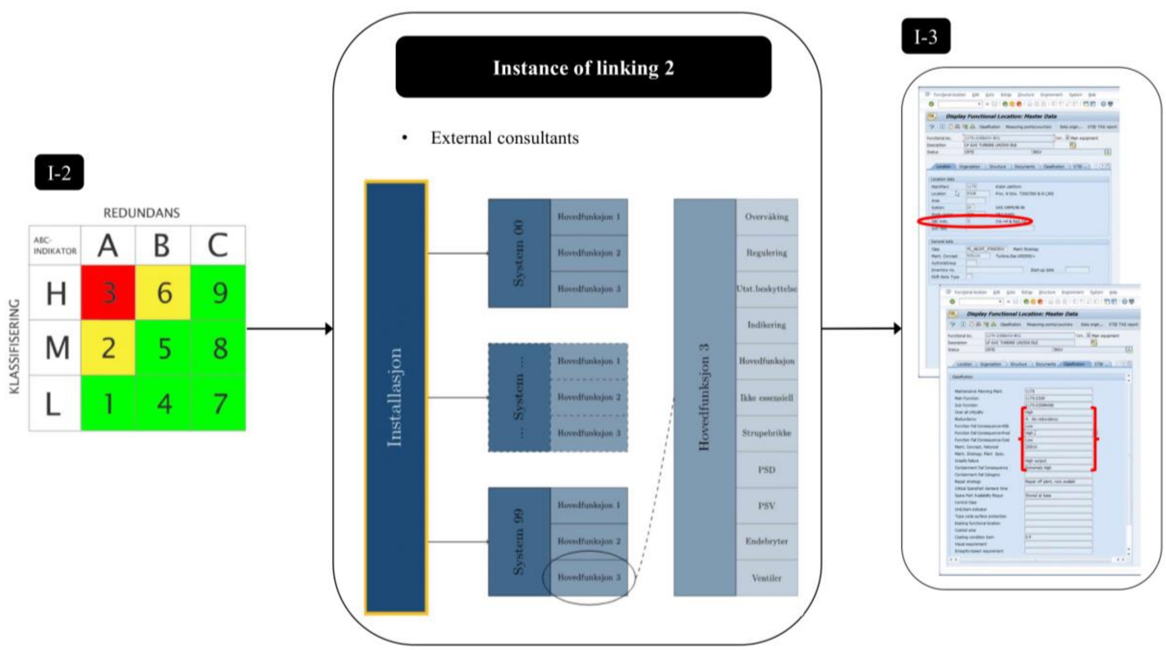

Figure 6 *Second instance of linking in the EnergyCo system of interlinked inscriptions—shows how the ABC indicator and the ERP tables were linked through the expertise of external consultants and their proprietary tool*

4.2.3 Instance of Linking 3: Automated Sourcing to MATE

As explained in the case description, "all" company data was gathered in a central database—OMNIA—with the aim of enabling EnergyCo to "respond to the need to effectively integrate and exploit emerging IT opportunities" (int_doc_6). This investment became an integral part of the large-scale digitalization strategy launched in 2017, which sought to both "improve safety and security of [EnergyCo] operations" and "drive cost reductions" (CEO EnergyCo).

Proponents of a balanced approach to maintenance believed that the data—or "facts"—needed to be analyzed to produce evidence-based suggestions for actions. To carve out concrete areas with the potential to support a successful tradeoff between financial performance and safety risks, an analysis tool—MATE—was developed that sourced data from OMNIA. The tool was a substantiation of dreams about fact-based maintenance operations:

> [MATE] is designed to present the facts, objective data, and analyses to disarm empty rhetoric from the union or offshore workers. […] For example, if [MATE] shows that mean time to failure for a valve is 150 years, then rhetoric about why you still need routine inspections and preventive maintenance should not trump facts. (Senior Analyst, from field notes taken during demonstration meeting)

Through extensive code scripts, MATE automatically sourced available maintenance data from OMNIA to identify areas for improvement and, thereby, aid analysts in providing recommendations for changes in maintenance programs. A Maintenance Analyst active in the development of the tool from the beginning explained:

> We figured out that we wanted to develop a tool or a dashboard that would help us to put an X on the map. [That indicated] areas for improvement, where it was smart to put down the shovel and start to dig after a treasure. […] In addition, when we believe we have found some opportunity for improvement, we want to have some pointers as to […] what direction the analysis should take. (Analyst 4)

"Improvement" was associated with the balancing of concerns about cost-efficiency and safety risks. In essence, a successful balance implied that costs were cut without safety being compromised or vice versa. MATE highlighted areas for improvement in at least two ways (I-4 in Figure 7).

First, MATE aimed to assist in prioritizing maintenance analysts' work by calculating a coefficient, which the analysts named "potential for improvement."[9] Maintenance Analyst 4 explained the reasoning behind the calculation:

> We said in the project that if you have a piece of equipment on which you plan to do a lot of preventive maintenance but you also have a low mean time between failures, in other words a low failure rate, and we have lost a high volume [of hydrocarbons due to the equipment failing], you have significant potential for improvement. […] If this number is large, [it is ranked highly] with a number between 1 and 500. (Analyst 4)

This analyst proposed that financial performance, formulated as costs related to hours of preventive maintenance and loss of income due to loss of volume, should be balanced with safety concerns. If equipment was statistically likely to rarely fail and the consequences of production loss were low, then maintenance activities should also be low. Equipment categories in which the data showed that maintenance activity was high despite the two other numbers being low were to be investigated more closely.

Second, to provide more specificity on how maintenance for equipment with a high a potential for improvement could be improved, MATE categorized specific equipment into action categories using a decision-tree algorithm (Figure 7, Instance of linking 3). These categories were aimed at assigning a particular action to all equipment in EnergyCo and they were designed to improve maintenance based on the equipment's historical trail of datapoints on reliability. However, the analysts could make their ambition of balancing between cost-efficiency and safety risks actionable for only a subset of equipment (dark blue histograms in I-4, Figure 7).

Importantly, the actions aimed at maintenance improvement were circumscribed by the equipment's safety classification—the ABC indicator. If equipment was categorized as non-safety (or production) critical (i.e., a green or yellow ABC indicator), then the algorithm suggested that a run-to-failure strategy[10] should be considered. The implications would be substantial cost savings, as maintenance activities could be limited to the time of breakdown only.

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[9] $PFI_i = \frac{Estm.\ PM\ hrs\ (yr)_i}{MTBF_i} \times Prod.\ Loss\ (Sm3)_i$, where i = equipment category.

[10] Run-to-failure maintenance, or unplanned maintenance, is a recognized maintenance strategy in which maintenance is suspended until equipment breakdown when such a breakdown poses negligible risks to safety or production processes. This strategy can be promoted based on its cost-effectiveness (Jardine et al., 2006).

For equipment categorized as safety (or production) critical (i.e., a red ABC indicator), the opportunity for action was limited. Some equipment categorized as a safety-critical element (SCEs) in the decision-tree algorithm was viewed as so critical to maintaining the integrity of the oil platforms that laws and regulations (issued by PSA) as well as internal governing documents included specific rules on their maintenance. Hence, the SCE units were sorted out early in the decision-tree algorithm to be handled by tools other than MATE.

Large proportions of safety-critical equipment were eligible for *conditional* changes in the maintenance interval depending on the criticality assessments and the record of functional tests (reliability data). These tests were conducted by offshore personnel on a regular basis as part of existing maintenance routines and aimed to detect the loss of function in equipment. If the record showed a trail of three or more successful functional tests, there were grounds for suggesting an extension of the maintenance interval.

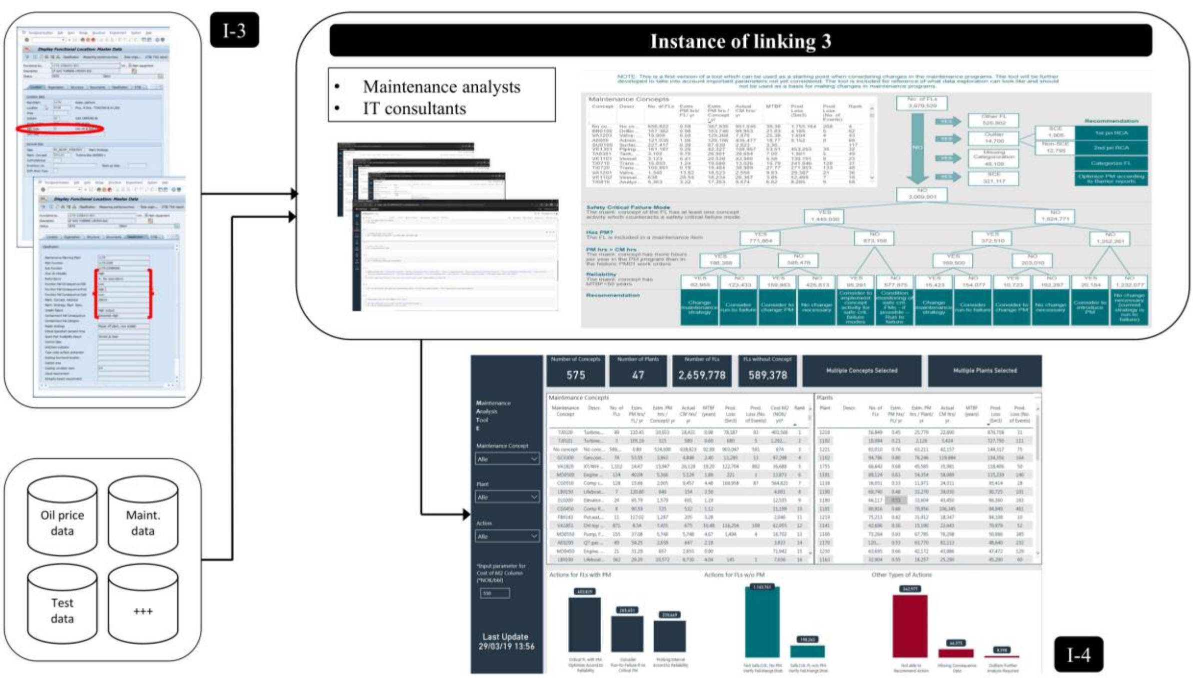

Figure 7 *Third instance of linking in the EnergyCo system of interlinked inscriptions–shows how the ERP tables (and other data sources) and MATE were linked though code scripts and a decision-tree algorithm*

The code scripts and the decision-tree algorithm extracted the ABC indicators from the ERP tables, combined them with other datapoints (predominantly reliability data), and sorted equipment into action categories. It thus formed the link that data had to travel to reach its 'final' destination. The MATE dashboard displays action recommendations aimed at enabling a balance between financial performance and safety risks. However, these recommendations had not yet had a material effect on maintenance practices at the time of the study.

4.3 Concealed Links

MATE was unable to realize the objective of balancing financial performance and safety risks in practice. "Facts" were not enough to reduce the size of the maintenance programs or make the offshore operations work in new ways.

The offshore operations were not particularly involved in the construction of MATE and similar inscriptions. These projects were mainly run by maintenance analysts to make their own work more efficient and their recommendations to operations more rigorous. The exclusion of operations in the development process did not go unnoticed by the analysts themselves.

> We have not received an order for this type of tool [MATE and other dashboards]. […] The reason why we started this was good, but if the customer does not exist, it tells you something about what you can expect about future use [of such tools]. (Analyst 6)

> **Were you involved in the design phase of this tool?** Not really. […] A group in Stjørdal developed it, and we were a little bit on the side of that process. We were asked from time to time, so we were a little bit involved, but… **Were you asked about what was important for you?** No, it was more about looking at functionality. (Analyst 8)

As the offshore operations were basically excluded from the development process, it was difficult for them to utilize tools like MATE and understand their role in, for example, striking a balance between financial performance and safety risk. Moreover, exclusion from and unfamiliarity with the development process made it difficult to trace the logic behind the recommendations in MATE. As a result, the actors faced with MATE's recommendations were overwhelmed because they did not know the source data or code scripts that were involved in constructing the recommendations:

> The drawback is that when I [use MATE to] challenge the organization and [people] have not used the tool, [they] are overwhelmed by the knowledge and an overview that [they] do

> not recognize or feel comfortable with. This is also how I feel when I am confronted with information and unable to find out what that information is rooted in or if I was supposed to know it. Of course, you feel a little embarrassed. We are, after all, working in a knowledge company with well-educated personnel with a lot of experience. (Maintenance Planners Team Leader D)

Tracing the "roots" of recommendations required deep knowledge of things like computer code as well as skills in mathematics and statistics, and experience with the maintenance-management discourse. For example, the decision tree's sorting of equipment required an understanding of the definition of an SCE, the logic of criticality assessments and the ABC indicator, and statistical formulas like mean time between failures (MTBF). Without this knowledge, MATE's recommendations were not decipherable and had to be trusted blindly, making actors uncomfortable.

Notably, how MATE and other tools arrived at recommendations was not usually intentionally concealed. For example, MATE's designers engaged in deliberate efforts to make all information regarding the tool's recommendation process available. Their intention was that MATE and the system of inscriptions to which it was linked should enable financial performance and safety risks to be balanced in practice.

> We have included an information button. [If you click it,] you will find an explanation of how the calculations are done. (Analyst 4)

To representatives of offshore operations, however, recommendations from tools like MATE seemed to come out of thin air, leaving them feeling patronized:

> We are in this process of [evaluating maintenance programs through analyses of data in tools like MATE] and it has been negatively received offshore. The people are pretty frustrated. […] Their criticism is that [changes] come very fast, so the people offshore feel patronized. (Operations Team Leader 2)

Although a system of interlinked inscriptions was constructed to achieve a balance between financial performance and safety risks in EnergyCo's maintenance operations, it was unable to realize this objective. The pathways linking the system together seemed to be concealed or at least less visible to certain actors, who then felt uncomfortable and patronized. This generally hampered their engagement in maintenance-improvement work.

Drawing on our findings, I now turn to a discussion of how the visibility of links—a property that is argued to be central for users' engagement with systems of interlinked inscriptions—is influenced by a particular social aspect: specialized knowledge.

5. Concluding Discussion

The extant literature has highlighted how inscriptions become involved in the realization of objectives by linking, for example, people, discourse, and physical entities together (Jordan et al., 2018; Qu & Cooper, 2011; Quattrone, 2009). More recently, the importance of systems of interlinked inscriptions for goal realization has been theorized and research has shown how these systems can be made effective through visual pathways with which actors can engage (Martinez & Cooper, 2019). However, how the visibility of pathways is conditioned and influenced has been largely neglected. Hence, I asked the following question: *How are the visual properties of links influenced?* In EnergyCo's system of inscriptions, one aspect is particularly influential for link visibility: actors' capacity for specialized knowledge. In this discussion, I aim to connect the findings to extant literature by reflecting on how actors' capacity for specialized knowledge influenced link visibility in each of the three instances of linking.

The workshop formed the link between PSA regulations and internal governing documents on the one hand and the ABC indicator inscription on the other. In other words, it served as a sociomaterial pathway outlining how these inscriptions were to be linked, and drew on both material objects and knowledgeable human agents. Importantly, the visibility of this particular pathway was influenced by the capacity for specialized knowledge among the human actors. In other words, differences in specialized knowledge bases between offshore representatives and onshore engineers contributed to the lack of ability or willingness to visualize a collective way forward. The onshore engineers usually failed to see past their general recommendations for equipment maintenance, while offshore representatives were so emersed in the details of the local context that they struggled to see how general recommendations might be useful.

Therefore, such workshops mobilized a particular sociomaterial combination to make the pathway between ambiguous rules and regulations and the ABC indicator visible. This combination involved the workshop leader's a priori understanding of conflicting specialized knowledge bases between onshore and offshore actors, the detailed ABC matrix (Figure 5, Instance of linking 1), and the external consultants' expertise in criticality assessments. The workshop leader first created consensus between opposing and knowledgeable actors. This required a laborious effort in terms of methodological demonstrations, active listening, goal identification, and social activities—all of which made subsequent work "much easier" (Workshop Leader). Aligned actors could look at the detailed ABC matrix, engage with the external consultants, quickly agree about the consequence classification of equipment, and then assign an ABC indicator that corresponds to the criticality assessment.

In the first and second instances of linking, the external consultants played an important role by providing "linguistic labels" and "orders" (Martinez & Cooper, 2019, p. 17) that structured and aligned. In other words, they constituted a visual pathway for the discussions between opposing actors that eventually resulted in consensus. In the workshop, they played a supportive role aimed at ensuring that agreements between the onshore and offshore actors were properly codified according to the uniform method of consequence classification. Their methodology and theoretical concepts, like the "functional hierarchy," "systems," and "main functions," provided a scaffold within which a visual pathway could be identified. This was particularly evident in the second instance of linking, where the link between the ABC indicator and the tables in the ERP system was made visual through the consultants' categories and the corresponding system. The ERP system did not have a classification module—the organization had to draw on the specialized knowledge of external consultants to make this particular pathway visible.

In the final instance of linking, specialized knowledge also played a role in relation to link visibility. However, it was closely connected to an amalgam of information technology and maintenance-management expertise. In this instance, the data in the ERP tables was linked to the MATE dashboard through code scripts and a decision-tree algorithm, which transformed the ABC indicator into action categories. Correct actions were determined by maintenance analysts' expertise in the optimization of maintenance practice (i.e., balancing cost concerns with safety risks) and turned into computer code. Moreover, the constitution of these action categories was not hidden. Instead, it was easily accessible through an "information button [explaining] all calculations" (Analyst 4) on the MATE dashboard. Therefore, the pathway and its features for ordering were highly visible to and accessible for actors. However, deciphering the decision-tree algorithm and tracing the logic of the code script was difficult without a capacity for certain specialized knowledge, which concealed the link between the ERP tables and MATE.

Across the instances of linking in EnergyCo's maintenance operations, the capacity for specialized knowledge influenced the visibility of sociomaterial links. Notably, the material pathways of the system of interlinked inscriptions in EnergyCo were there, but they were made more or less visible by actors' capacity for specialized knowledge. This finding also shows that material and visual pathways in a workspace of interlinked inscriptions does not always contain the scripts (D'Adderio, 2008) that users need to engage with the system. Although material pathways might provide some guiding "rules and procedures" (D'Adderio, 2008, p. 773) on using the system, the material must sometimes be supplemented with socially engendered guidelines in order to become visible. If these supplementary activities are not performed, "patchwork-type interventions" (Martinez & Cooper, 2019, p. 2) become difficult and the objectives of the interlinked system of inscriptions are not realized.

I contribute to the literature on inscriptions (e.g., Martinez & Cooper, 2019; Robson, 1992) by highlighting how a certain property of sociomaterial pathways—visibility—is influenced by certain social aspects. Specifically, I show that we should pay attention to actors' capacity for specialized knowledge if we are to understand the visibility of links. In addition, the findings presented here show that although studies of singular inscriptions provide valuable insights, we should pay equal attention to the properties of links that bind them together in systems of management and the elements that influence them. While material properties of visual pathways matter for users' abilities to engage with a system of interlinked inscriptions (Martinez & Cooper, 2019), I demonstrate how actors' capacity for specialized knowledge can condition the visibility or concealment of material pathways.

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7. Appendix

Table 5 *Interviews*

#	Role	Date		Round	hh:mm	Recorded
1	Senior Analyst	13/03/19		1	02:00	N
2	Financial Controller 1	20/03/19		1	00:56	Y
3	External Maintenance Consultants	09/04/19		1	02:00	N
4	Senior Engineer 1 and Safety Representative	11/04/19		1	01:00	N
5	Senior Analyst, Analysts Team Leader and Analyst 1	11/04/19		1	01:30	N
6	Operations Planner 1	12/04/19		1	00:50	Y
7	Operations Planner 2	25/04/19		1	00:53	Y
8	Senior Engineer 1	30/04/19		1	01:00	N
	Total of eight interviews in Round 1					
9	Analyst 1	14/10/19		2	01:00	N
10	Analyst 2	16/10/19		2	01:05	Y
11	Data Governance Manager	16/10/19		2	01:00	N
12	Analyst 3	16/10/19		2	00:55	Y
13	Analyst 4	17/10/19		2	00:53	Y
14	Senior Performance Analyst 1	21/10/19		2	01:45	N
15	Analyst 5	22/10/19		2	01:00	N
16	Analyst 6	23/10/19		2	01:16	Y
17	Analyst 7	23/10/19		2	01:20	N
18	Analyst 8	23/10/19		2	01:04	Y
19	Analyst 9	24/10/19		2	00:58	Y
20	Analysts Team Leader	25/10/19		2	01:00	N
21	Planner Team Leader 1	28/10/19		2	00:39	Y
22	Planners Team Leader 2	29/10/19		2	00:41	Y
23	Integrated Operations Center Leader	30/10/19		2	00:45	N
24	Operations Team Leader 1	31/10/19		2	00:56	Y
	Total of 16 interviews in Round 2					
25	Analysts Team Leader	14/02/20		3	01:38	Y

26	Planner Team Leader 3	11/06/20	3	00:43	Y
27	Operations Planner 3	17/06/20	3	00:37	Y
28	Planner Team Leader 4	18/06/20	3	00:58	Y
29	Operations Team Leader 2	13/08/20	3	01:03	Y
30	Union Leader	21/08/20	3	00:56	Y
31	Operations Electrician	31/08/20	3	01:19	Y
32	Operations Team Leader 3	04/09/20	3	01:03	Y
33	Analysts Team Leader	11/09/20	3	00:30	N
34	Predictive Maintenance Team Leader	12/01/21	3	01:00	Y
35	Predictive Maintenance Analyst	12/01/21	3	00:56	Y
36	Analyst 4	14/01/21	3	00:57	Y
37	Analyst 10	14/01/21	3	01:01	Y
38	Analysts Team Leader	28/01/21	3	00:35	Y
39	Analyst 4	22/09/21	3	00:15	Y
40	Workshop Leader	29/09/21	3	01:25	Y
	Total of 16 interviews in Round 3				

Table 6 *Selection of retrieved documents and media*

#	Code	Media type	Content description	Retrieved
1	int_doc_1	Document	Report from external consultancy on reclassification project in EnergyCo's maintenance operations	12/08/2019
2	int_doc_5	Document	Presentation slides about OMNIA and new digital opportunities for energy production	06/11/2020
3	int_doc_2	Document	Article about launch of digital strategy with interviews of CEO and COO	26/11/2020
4	int_doc_4	Document	Presentation slides on EnergyCo's technology strategy	26/11/2020
5	int_doc_3	Document	Article about how digitalization is changing EnergyCo with interviews of two employees and CDO	23/04/2021
6	int_doc_6	Document	Article about the purpose of OMNIA by CIO of EnergyCo	23/04/2021
7	int_doc_7	Document	Article about launch of IOC center with interviews of top management	04/05/2021
8	int_doc_8	Document	EnergyCo corporate presentation	20/05/2021
9	int_doc_9	Document	E-mail correspondence with Analyst 4 about criticality assessments	16/09/2021
10	int_doc_10	Document	EnergyCo website page on health safety and security	14/10/2021
11	ext_doc_1	Document	Petroleum Safety Authority website page on its role and responsibilities	15/10/2021

Chapter 3

Knowledge Gained, Knowledge Lost: The Paradox of Digitalizing Knowledge Work

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Abstract

Research has shown how digitalization allows organizations to gain knowledge based on data analytics, machine learning, and other technologies, while at the same time demonstrating how extensive reliance on digital data traces can entail loss of knowing. To further our understanding of this conundrum, we adopt a dialectical perspective to analyze how tensions between gaining and losing knowledge manifested in digitalization of condition-based machine maintenance at a multinational energy company. Relying on extant literature and empirical insights, we identify three latent tensions – authority tensions, knowing tensions, and valuation tensions – related to digitalizing knowledge work, and analyze how they were constructed and manifested in the digitalization of machine maintenance at the energy company. As a result, we reveal digitalizing knowledge work as a an inherently paradoxical process where increasing available data to improve task performance can simultaneously decrease the capability to perform the task effectively. We demonstrate how this paradox may spur spirals of unintended consequences during digitalization of knowledge work and discuss implications for theory and practice.

Keywords: Digitalization, knowledge work, tensions, paradox, unintended consequences, case study

1. Introduction

Digitalization has led to reconfigurations of work, knowledge, and power (Faraj et al., 2018; Zuboff, 1988), recently driven by data analytics, machine learning, and other emerging technologies (Benbya et al., 2021; Yoo, 2010), generating unprecedented volumes and diversity of data and engendering increased reliance on data in work tasks (Constantiou & Kallinikos, 2015a). The rapidly expanding reliance on quantities of data creates qualitative shifts in how knowledge work is configured (Faraj et al., 2018; Monterio and Østerlie, 2020), especially in how knowledge is produced and utilized (Markus, 2015; Newell, 2015; Newell & Marabelli, 2015;). While these developments allow organizations to gain knowledge from expanding volumes and specters of data, they simultaneously can entail loss of knowing (Bailey et al., 2012; Zuboff, 1988), as relying on knowledge from patterns in data may lead to less relational and contextual knowledge (Faraj et al., 2018; Pachidi et al., 2020). Despite evidence of such tensions, however, empirically based theorization on how tensions manifest in digitalizing knowledge work is still scarce.

Adopting a dialectical perspective on the digitalization of work allows us to understand organizations as continually managing tensions that are not easily resolved by favoring one polarity or balancing between them (Hargrave, 2021; Benson, 1977). Rather than dissolving through organizational responses, tensions can become objectified or transformed into new forms through interplay between their opposites and responses to them (Hargrave & Van de Ven, 2017; Smith & Lewis, 2011; Van de Ven & Poole, 1995). Through this dialectical process, tensions and their responses can be or become paradoxical, as opposites that form "contradictory yet interrelated elements that exist simultaneously and persist over time" (Smith & Lewis, 2011, p. 382). Studying tensions, therefore, brings us to the heart of the challenges involved in managing and governing organizations (Lindgren et al., 2021) by investigating, for example, how managers balance exploration and exploitation (Andriopoulos & Lewis, 2009), how platform owners regulate their ecosystems to foster both stability and innovation (Wareham et al., 2014), and how software vendors negotiate local customer needs with global standardization needs (Pollock & Williams, 2008).

Applying a dialectical perspective to digitalization, we ask: *How do tensions manifest in digitalizing knowledge work?* To address this research question, we performed a case-study of condition-based machine maintenance in a multinational energy company, EnergyCo (a pseudonym). Building on recent research on how the use of data analytics reconfigures the knowledge structures and processes of organizations (Constantiou & Kallinikos, 2015a; Faraj et al., 2018; Kitchin, 2014; Monteiro & Parmiggiani, 2019), condition-based machine maintenance can be said to be a paradigmatic example of the data-driven logic of contemporary digitalization (Jardine et al., 2006; Jonsson et al., 2018). It involves moving from practices where machinery is maintained through frequency-based routine inspection programs and onsite personnel's intimate knowledge of machines, towards practices where the when, how and if of machine maintenance is determined by remote experts based on trends in historical and real-time data. As in other industrial contexts, maintenance is a key contributor to value creation and safety and transforming it into a data-driven process is an important part of EnergyCo's digitalization agenda.

To analyze the case, we first reviewed existing literature on tensions in digitalizing knowledge work, drawing on recent research by Pachidi et al. (2020). The authors suggest that contested forms of knowledge work can be understood by analyzing how authority and power are distributed related to knowing, how knowing is performed in practice, and how entities and events are evaluated as a basis for knowing. These perspectives allowed us to derive three latent tensions in digitalizing knowledge work from the literature: authority tensions, knowing tensions, and valuation tensions. We proceeded to analyze our empirical material through dialectical inquiry into these latent tensions to see how they were constructed and manifested in EnergyCo's digitalization process. Drawing on these conceptual and empirical insights, we develop a model of how tensions in digitalizing knowledge work are constructed. We then demonstrate the paradoxical nature of this construction, revealing *digitalizing knowledge work as an inherently paradoxical process where increasing data to improve task performance can simultaneously decrease capability to perform tasks effectively*. This allows us to discuss how digitalizing knowledge work can spur spirals of unintended consequences contingent on organizational responses.

2. Theoretical Foundations: Tensions in Digitalizing Knowledge Work

That tensions and paradoxes underlie organizational trajectories is an established maxim in technology and organizational studies (Benson, 1977; Brooks et al., 2020; Cho et al., 2007; Hargrave & Van de Ven, 2017). It posits that "the organizational entity exists in a pluralistic world of colliding events, forces, or contradictory values that compete with each other for domination and control" (Van de Ven & Poole, 1995, p. 1995). Understanding how tensions shape trajectories and manifest in the perceptions and behavior of actors is especially important in relation to digitalization, as these processes are characterized by people navigating complex changes (Brooks et al., 2021; Farjoun, 2016; Smith & Lewis, 2011). Digitalization enables, for example, new forms of geographically distributed work, often leading to knowledge asymmetries and tensions between central control and local autonomy (Brooks et al., 2021). In turn, digitalization trajectories are dialectical, continuously shaped by the manifestation of tensions and the responses they elicit (Wimelius et al., 2021). To provide a theoretical background to our study, we first elaborate on the theoretical foundation of investigating tensions and then use this lens to describe tensions of digitalizing knowledge work in existing literature.

2.1. Dialectical and Paradoxical Inquiry into Tensions

Tensions and paradoxes have previously been investigated through dialectical and paradoxical inquiry (Farjoun, 2016). Both approaches are mindful of paradoxes, as tensions that consist of "contradictory yet interrelated elements that seem logical in isolation but absurd and irrational when appearing simultaneously" (Lewis, 2000, p. 760), but the forms of inquiry differ. Dialectical inquiry assumes that paradoxes do not exist *ex ante* and directs research towards studying how they are socially constructed (Farjoun, 2021), while paradoxical inquiry assumes that paradoxes always exist and directs research towards studying how they are responded to over time (Smith & Lewis, 2011). We build on recent organizational research suggesting that investigating tensions and paradoxes requires combining dialectical and paradoxical inquiry to allow a richer understanding of how tensions become manifest and play out (Hargrave, 2021; Hargrave & Van de Ven, 2017). This approach allows us to use dialectical inquiry to analyze how paradoxes emerge, recur, and are responded to through sociomaterial construction and action (Hargrave, 2021).

This combined form of inquiry accentuates how tensions can lead to transformations of their contradictory elements or the formation of new ones (Farjoun, 2021; Hargrave, 2021). Dialectical inquiry describes these processes as ongoing interplay of tensions that continuously shape the phenomena they constitute (Putnam, 2015). For example, contradictions between industry discourse on digitalization strategies and the challenges of implementing such strategies in organizations with a high degree of legacy systems can lead to transformations in both discourse and system architecture (Øvrelid & Bygstad, 2019). Combining dialectical and paradoxical inquiry emphasizes the recurrent manifestation of tensions that, because of their interdependence, become paradoxical and cannot be resolved by favoring one polarity (Brooks et al., 2020; Farjoun, 2010). For example, vendors of generic software must continuously balance the need to make their solutions generic with local customer needs (Li & Nilsen, 2019). Failing to negotiate this balancing can lead to vicious cycles of manifestations and responses where one polarity of the tension becomes increasingly repressed (Smith & Lewis, 2011).

Accordingly, we understand tensions as totalities consisting of two opposing poles (Benson, 1977; Cho et al., 2007; Putnam, 2015). As a totality, a tension has two defining characteristics: its identity and the dialectic relationship between the opposites (Bosserman, 1995; Cho et al., 2007;). The identity refers to the tension as a whole and how the opposing poles coexist (Cho et al., 2007). The dialectic relationship describes how the poles are related and the dynamics impelling change in this relationship (Bosserman, 1995; Cho et al., 2007). Furthermore, this form of analysis assumes latent tensions in all processes. For example, in standardization processes, there is a latent tension between the poles of the local and the global, where stable standards are necessary for global interoperability, but flexible standards are necessary for local adaptability (Braa et al., 2007; Lindgren et al., 2021). The tension is latent, because standardization processes by definition have both global and local dependence, making emergence of tensions an inherent possibility. However, whether these tensions become manifested – and the peculiarities of their manifestation – depends on how the processes play out through the experiences, activities, and interactions of the participating actors (Benson, 1977; Smith & Lewis, 2011; Van de Ven & Poole, 1995). In other words, the paths to manifestation are socially constructed and determined by the actions of contingent actors (Farjoun, 2016; Smith & Lewis, 2011). The process is often haphazard, and the ways in which tensions become manifest impact how they can be navigated.

Scholars have pointed out some recognizable patterns in how tensions become salient. First, tensions manifest in conditions characterized by plurality of perspectives, scarcity of resources, and change (Smith & Lewis, 2011). Second, the dialectic relationship between the poles of a tension can typically be constructed through logics of complementarity, mutuality, or polarization (Bosserman, 1995; Lindgren et al., 2021). The first two imply that existence of one polar element strengthens the other, by one element either complementing or mutually implying the other (Bosserman, 1995). Polarization, on the other hand, implies conflict between the elements, as choosing one will overshadow the other (Bosserman, 1995). As such, paradoxes are tensions that seem polarizing, but are mutually implicating in their relationship. Third, salient tensions can become recurrent, self-reinforcing, or transformed by the way they are constructed and responded to (Farjoun, 2016; Hargrave & Van de Ven, 2017). Tensions that first become manifest in people's perceptions can become objectified through construction of institutional and material structures that solidify them (Hargrave, 2021). While these patterns give us insight into how tensions generally become salient, how this plays out in the digitalization of knowledge work has not yet been studied.

2.2. Latent Tensions in Digitalizing Knowledge Work

Digitalization entails a process that decouples the informational from the physical (Lycett, 2013; Zuboff, 1988). Physical entities can provide information through their own manifestation, as a broken pipe in a piece of machinery both provides information that it is broken and what possibly caused it. Digitalization decouples this information by producing and consuming digital technology representations of the physical phenomenon (Burton-Jones & Grange, 2012; Jonsson et al., 2018). Representations as structures of data tokens that represent some state or aspect of a phenomenon (McKinney & Yoos, 2010), can again be re-represented through processing and combinations with other data, which recursively enables new forms of information. As the representational capacities of digital technologies continuously become more powerful (Monteiro & Parmiggiani, 2019), digitalization is radically transforming how knowledge work is performed (Faraj et al., 2018), entailing various tensions.

Reviewing existing literature to discern latent tensions in digitalizing knowledge work, we followed the proposition of Pachidi et al. (2020) that contestations arising from new forms of knowledge work can be studied based on "the specific knowing practices through which actors develop and use knowledge; the valuation schemes through which actions, people, and things are evaluated; and the authority arrangements that determine which actors have control over how the work is performed in certain tasks". In other words, the authors suggest a coupling between how knowledge is governed through power and authority arrangements, how knowledge is obtained through data, and how entities and events are evaluated in the use of data. Reading existing digitalization literature through this lens, we suggest digitalizing knowledge work involves latent tensions of authority, knowing and valuation (Table 7).

Authority Tensions. Digitalization radically widens the scale and scope of information people can produce and use in their work (Monteiro & Parmiggiani, 2019; Newell, 2015; Zuboff, 1988). At the same time, digitalization leads to centralization of power (Doolin, 2014; Leclercq-Vandelannoitte, 2014). Managers can access accumulated and calculated information that previously was under the purview of individual workers, which means that they can increase their authority of how tasks are performed (Zuboff, 1988), as central actors decide the protocols and standards through which task-related representations are structured (Bucher, 2018). Organizations also amass large amounts of data, which can be used to nudge behavior and make decisions that impinge on the distributed actors (Aaltonen & Tempini, 2014; Zuboff, 2019). As such, digitalizing knowledge work involves tensions between planned authority that is embedded in the task organization and situated authority that emerges during task performance.

Authority tensions in digitalization are often tied to expertise as different placement of authority determines who can take on an expert role (Pachidi et al., 2020). This can also imply loss of expertise, in that centralized authority through digitalization can entail that local experts lose authority (Orlikowski & Scott, 2014; Scott & Orlikowski, 2012). For example, as hotels are ranked through large amounts of user-generated data, the role of travel experts who previously used their experience and expertise to review hotels become obsolete (Orlikowski & Scott, 2014; Scott & Orlikowski, 2012). Tensions in who is authorized to be an expert are in this way inherently tied to tensions in how work is organized (Pachidi et al., 2020). As a result, experts can lose status, tasks, and even their roles, as the authority over tasks are delegated to data analysts that are experts on data and statistics rather than the specific phenomena involved (Markus, 2017; Pachidi et al., 2020).

Knowing Tensions. The organizational shifts toward representation-based knowing (Bailey et al., 2012; Newell, 2015; Zuboff, 1985) contrasts with experience-based knowing, where knowledge is produced through interaction and experience with the phenomenon itself (Bailey et al., 2012). Digitalization entails that workers can obtain knowledge of entities that are far away in time and space (Mikalsen & Monteiro, 2021) and utilize new methods of knowing in tasks through crowds, sensors, and simulations. Moreover, such developments can trigger recurrent tensions (Bailey et al., 2012). As such, digitalizing knowledge work involves latent tensions between knowing practices based on experience with phenomena and knowing practices based on representations of them (Pachidi et al., 2020).

Knowing tensions can manifest in the form of uncertainties as to whether relevant parts of reality are represented correctly (Parmiggiani et al., 2022), making workers unsure whether they are acting on correct information (Zuboff, 1988) and less effective in their tasks when there are insufficient opportunities to engage and build on experience-based knowing (Bailey et al., 2012). While workers may want to understand the relation between their experiential knowledge of a phenomenon and representations of it and have the opportunity to triangulate between different forms of knowing (Østerlie & Monteiro, 2020), knowing tensions get accentuated by introduction of new professional groups in the organization that predominantly rely on representation-based knowing versus existing groups that know through experience (Pachidi et al., 2020). Knowing practices and methods build on particular vocabularies and ways of working, and the meeting between these practices can create tensions.

Valuation Tensions. As information is decoupled from physical phenomena through digitalization, knowledge work can be rationalized through standardization of information and comparative quantification across contexts (Alaimo & Kallinikos, 2022; Lycett, 2013;). This enables increased efficiency in working across contexts, with the risk that tasks may be less fit to the contingencies of specific phenomena (Alaimo & Kallinikos, 2022). Consequently, digitalizing knowledge work involves tensions between valuing the efficiency of task rationalization and valuing the diligence of contingent and localized task performance.

To exemplify, sales account managers value their own practice of treating customers as individuals, gained through personal contacts (Pachidi et al., 2020). The introduction of data analysts that value the increased efficiency of working with patterns in customer data can create salient tensions between the two groups (Pachidi et al., 2020). Valuation tensions becomes especially visible when knowledge workers are required to respond to increased valuation of rationalized task performance. For example, the way higher education institutions are numerically ranked based on standardized criteria shapes how students evaluate these institutions, which in turn impacts how institutions evaluate themselves (Espeland & Sauder, 2007). This tension is especially visible in the platform economy, whose emergence is tightly coupled to the possibility of treating individual cases through standardized and quantified means. Digital platforms enable efficient transactions at scale because buyers and sellers are evaluated based on standardized "rankings, classifications, stars and other symbols" (Kornberger et al., 2017, p. 81). This can create tensions between knowledge workers in the platform ecosystem, who treat their workplaces as individual cases and see calculated scores across cases as reductive and misleading (Orlikowski & Scott, 2014).

Table 7 *Latent tensions in digitalizing knowledge work*

Latent tension	*Definition*	*References*
Authority	Digitalizing knowledge work involves tensions between planned authority that is embedded in the task organization and situated authority that emerges during task performance.	Zuboff, 1988; Doolin, 2014; Leclercq-Vandelannoitte, 2014; Scott & Orlikowski, 2012; Orlikowski & Scott, 2014; Newell, 2015; Monteiro & Parmiggiani, 2019; Markus, 2017; Pachidi et al., 2020
Knowing	Digitalizing knowledge work involves tensions between knowing practices based on direct experience with phenomena and knowing practices based on representations of them.	Zuboff, 1985; Bailey et al., 2012; Newell, 2015; Østerlie & Monteiro, 2020; Parmiggiani et al., 2021
Valuation	Digitalizing knowledge work involves tensions between valuing the efficiency of task rationalization and valuing the diligence of contingent and localized task performance.	Lycett, 2013; Espeland & Sauder, 2007; Kornberger et al., 2017; Pachidi et al., 2020; Alaimo & Kallinikos, 2022; Orlikowski & Scott, 2014

3. Research Methods

Case study research is a well-recognized method for theory building (Eisenhardt, 1989). It is particularly useful for in-depth investigation of technology "in its context" (Benbasat et al., 1987, p. 369) through "how" questions (Benbasat et al., 1987, p. 370), and is as such an appropriate methodology for addressing our research question. The approach acknowledges the organizational world as socially constructed (Berger & Luckmann, 1966) and allows for delving deep into the construction process by engaging with the "knowledgeable agents" (Gioia et al., 2013, p. 17) involved in it.

3.1 Case Description

Our empirical material originates from a longitudinal single case study of digitalization in EnergyCo. The company was established in the early 1970s following the discovery of substantial reservoirs of hydrocarbons in the Norwegian North Sea. From its establishment, EnergyCo has been closely connected to the Norwegian state as majority owner and has through its history mainly operated within the petroleum industry, currently with approximately 21,000 employees in more than 30 countries. Its main operations are still located on the Norwegian continental shelf with 42 relatively autonomous offshore production platforms. The offshore operation is supported by a substantial onshore organization providing – *inter alia* – maintenance planning and analysis.

Due to the challenging Arctic environment of the North Sea, attention to safety has always been and remains vital for EnergyCo. Events like helicopter accidents and explosions in the early years of operation have impressed a strong safety culture, which greatly influences work practices. Coupled with a corporate vision of "zero harm" it is practically unacceptable to take risks that can compromise safety. EnergyCo's operations are, therefore, as profitable as they are dangerous, a tension that must be balanced continuously. Negotiating this tension requires balancing between distributing human resources across platforms and centralizing them onshore. Offshore manpower reduces safety risk as they draw on extensive experience with platform-specific idiosyncrasies to effectively handle unanticipated equipment breakdown and maintain platform integrity. Having personnel offshore, however, incur substantial costs. Centralization of expertise onshore is an alternative approach, where limited personnel can serve all platforms. This requires, however, digital technology to represent local offshore realities so that operations can remain safe.

Since 2015, EnergyCo has increasingly centralized operations by continuously investing in the opportunities offered by digital technology. A company-wide digitalization strategy was launched in 2017 with ~350 million USD allocated to digitalization. Several of the projects initiated by this strategy are linked to data analytics and visualization for processes improvement. Maintenance of offshore machinery and equipment was identified as a particularly suitable organizational process for digitalization. Accordingly, several units have been established to drive digitalization of maintenance, two of which we engaged with for data collection: the Maintenance Analysis Unit (MAU) and their Digital Maintenance Visualization and Analysis (DMVA) project, established in 2017 to design digital technology for analysis and visualization of historical hand-reported maintenance data; and, the Integrated Operations Center (IOC) and their Predictive Maintenance Unit (PMU), established in 2019 to design solution for analyzing real-time sensory data to predict equipment failure.

3.2 Data Collection and Analysis

We had access to the research site through a research collaboration on digitalization in EnergyCo, based on a long-standing relationship between one of the author institutions and the company. As such, EnergyCo was already acclimatized and welcoming to the presence of researchers. Few restrictions were, therefore, put on our research process, other than reserving the right to control research reports for process sensitive information and intellectual property. Through an initial meeting with the Chief Digital Officer (CDO) and the Chief Analysts of the Finance and Control Department, we identified the maintenance process as a suitable empirical setting for studying digitalizing knowledge work, as tensions are frequently experienced in this context.

Our empirical material includes semi-structured interviews, observations, and internal and external documents. We conducted 40 semi-structured interviews from March 2019 to September 2021 in three separate rounds (Table 8 in Appendix). We conducted the first round of interviews from March to April 2019, including eight exploratory interviews in the maintenance operation. Questions were designed to identify digitalization projects within maintenance for in-depth study. The interviews directed us to the DMVA project within the MAU.

The second round of interviews transpired in October 2019. One of the authors spent three weeks on premise, following up on the direction set by the initial interview round, conducting sixteen additional interviews with informants from the DMVA project and from the wider maintenance operation. Questions were specifically directed towards design and use of digital technology for informant work. In addition, observations were conducted to broaden our understanding of digitalization in maintenance work. The interviews and observations showed that several units in EnergyCo were working on analysis of maintenance data for process improvement. One of these was the PMU in the IOC.

The third round of interviews stretched from November 2019 to September 2021. These interviews were conducted to provide supplementary data that were important for our theorization. For example, interviews with informants from the PMU were conducted to broaden our understanding of how digitalization of maintenance work was approached from different organizational units. Moreover, we sought to collect additional data on the operational perspective on digitalization as previous interviews indicated that their use and perception of technology differed from the onshore actors'.

Finally, throughout all periods, but particularly during the fieldwork period, we collected and analyzed a substantial number of documents (Table 9 in Appendix) to triangulate data from interviews and observations. A majority of the documents contained sensitive information, and access was restricted to on-premise viewing. In these instances, relevant information was noted in a fieldwork journal. We recorded and transcribed the majority of the interviews. When interviewees felt that they could speak more freely without being recorded, we took notes during the entirety of the interview and wrote an extensive summary directly following interview completion. The data collection concluded in September 2021 when we experienced theoretical saturation (Eisenhardt, 1989) as interviews in the third round only provided incrementally interesting points. The vast material we had collected up until this point contained several interesting pathways we could follow to address our research question.

We conducted data analysis as a distinct, but interwoven process in a predominantly inductive approach to data collection and analysis (Gioia et al., 2013). That is, we collected data from interviews, observations and documents and performed simultaneous data analysis (Langley, 1999; Locke & Golden-Biddle, 1997) by recursively jumping between empirical material and conceptualizations. This sensitized (Timmermans & Tavory, 2012) us to potentially interesting theoretical phenomena over time.

To allow insights to inductively emerge, we paid close attention to the formulation of our initial interview protocol (initially framed by the theoretical concepts of digitalization, big data and management control), but we were open to its gradual revision in case of mismatches between our anticipated conceptualizations and what the informants ended up talking about. That is, we predominantly listened carefully to the informants in the first round of interviews about what they considered relevant in relation to digitalizing knowledge work. Following informant experiences, we sought to establish a more detailed description over the actors in the maintenance process and where and how digitalization was implemented in the second round of interviews. Hence, our interview protocol shifted to focus on informants' general view of digitalization and how it influenced their work. These interviews made evident an array of tensions, which became our first-order concepts (Table 10 in Appendix). Although other first-order conceptualizations of such a vast dataset are plausible, we chose to limit our attention to tensions as we experienced them as the most dominant. Data not perceived as relevant to this conceptualization was thus excluded from further analysis.

Through a conjoint process of searching for literature on tensions and directing further interviews towards teasing out different manifestations of tensions in EnergyCo maintenance, we were able to formulate theoretical second-order concepts – or some "deeper structure" (Gioia et al., 2013, p. 20) to the inductively derived first-order concepts (Table 10 in Appendix). Our predominantly inductive approach then transitioned into an abductive process (Alvesson & Kärreman 2007; Timmermans & Tavory, 2012) as we held on loosely to our initial theoretical categories and remained open to our empirical material moving us in unexpected directions regarding relevant theoretical phenomena. Finally, because the literature on tensions is vast, we needed guidance on linking the categories from our empirical material to theoretical concepts. We found it in recent work by Pachidi et al. (2020) from which we developed the latent tensions in digitalizing knowledge work.

4. Empirical Findings

We present our analyses of how tensions manifested in digitalizing knowledge work at EnergyCo by drawing on the latent tensions of authority, knowing, and valuing (Table 7). First, we elaborate on tensions in authority to reveal how digitalization of work brought to the front the difference between planned and situated decision authority. Second, tensions in knowing reveal how people disagreed on whether to trust representations or situated experience in digitalized work. Third, we show how digitalizing work surfaced tensions in valuation related to efficiency of task rationalization or diligence of contingent and localized task performance in maintenance.

4.1 Authority Tensions

There are three overlapping, but distinguishable roles with associated responsibilities making up EnergyCo's *maintenance loop*: experts, operations, and analysts. An analyst explains:

> Those offshore [operations] execute the maintenance that the experts onshore have specified for the company [...] The experts design maintenance concepts that are general recommendations for maintenance [...] of equipment. Then, a maintenance program is made by the experts and sent to the ocean [...] It is the reports from the maintenance executed based on this program that we as an analyst group analyze [...] and suggest changes in maintenance based on. (Maintenance Analyst D)

The experts are generally well-educated engineers specialized in specific equipment and its role in wider technical systems. They are responsible for specifying the how and when of equipment maintenance and formalizing that into a *maintenance concept*. The concepts are assembled into overarching *maintenance programs* linked to specific platforms. The ambition is pre-planning of maintenance activities to prevent equipment breakdown and subsequent production stops or dangerous incidents. An expert leader elaborates:

> The maintenance programs are owned by the expert leaders. They are to know what kind of grease that is to be used for a valve and how often it is to be applied. They are experts in [their field] and they are the ones that are to have an opinion about this. (Maintenance Expert Team Leader B)

The experts are not, however, sovereigns that can dictate other actor groups. Their work is restricted to quality assurance of technical content in maintenance programs:

> The experts really just own the technical content in a project, relating to what you need to do in order to preserve the integrity of the equipment [...] That [operations] do the things that are agreed upon has nothing to do with the expert leader's responsibility. (Maintenance Expert Team Leader A)

Hence, execution of maintenance programs is delegated to operations which are responsible for reporting on their work by writing *notifications.* These records are "extremely important" and "form the basis for analyses and things that are done" (Maintenance Expert A) to improve maintenance programs according to the condition of equipment on site. They are "the history carriers" (Maintenance Analyst D) of equipment, ideally revealing its "performance" (Maintenance

Operations Team Leader B) and informing decisions regarding changes in maintenance work. An operations team leader summarizes:

> We are responsible for executing and reporting back. Providing input so that we can put the right technical content in the program. So, we kind of borrow the platform and steward it from the guidelines that [experts give us]. (Maintenance Operations Team Leader C)

Ideally, the maintenance loop should be a “learning loop” (Maintenance Expert Team Leader C). “Right technical content in the program” should be approximated as notifications flow from the ocean to experts onshore, making maintenance both safe and efficient, or what some refer to as “optimal”:

> The intersection between least amount of hours and highest possible [performance] on the same equipment […] is what we have to come as close to as possible [...] towards the more optimal. (Maintenance Expert Team Leader C)

Experts and operations, then, are interlocked in a mutually dependent relationship of “collaboration” (Maintenance Expert Team Leader B), even though decision rights on changes in maintenance lie with the experts. Notifications, however, pass through the analysts before reaching the experts:

> Each specific platform executes their maintenance and sends back reports. We analyze those and can then say something about whether we must do more, or if we can do less, or do something differently. (Maintenance Analyst D)

Analysts “use the data that are imputed” (Maintenance Analyst D) to support and “challenge” (Maintenance Analyst I) experts through highlighting “areas of improvement” (Maintenance Analyst D) and suggestions to “optimize” (Maintenance Analyst E) maintenance programs. Experts value their contribution:

> We expect to get that input from them. It’s about roles, who does what [...] What the analysts deliver to us is important. They help us with data collection and we get the analyses we want. (Maintenance Expert Team Leader A)

Even though authority arrangements seem clearly defined, the maintenance loop does not always flow frictionless. One contributing factor is frequently pointed out by informants: poor data quality which impedes the trustworthiness of analyses:

> I totally agree that we should develop dashboards [for maintenance], but they are worthless if we don't have control of our fundamental data first. That means the [equipment] data must be right […] and we must have right reporting [practices]. If we don't have that, we can make as many dashboards as we want. (Maintenance Expert A)

Some argue that poor data quality emanates from haphazard reporting routines and a shallow understanding of the importance of good-quality notifications in the maintenance loop:

> It varies a lot how skilled the individual offshore worker is to input things rightly into the system. (Union Leader)

> I think this is what we have to improve a bit, getting the understanding through the [whole organization about] why it is important that the data are imputed. (Maintenance Operations Team Leader C)

Others allude to operations being fully aware of dubious reporting routines:

> Maintenance operators also make mistakes. Often, we find small faults, but don't bother to enter into the system that we found it and fixed it. [In the system] it will look like we have not had a failure in 10 years. So, of course the [onshore experts and analysts] say that we don't need to do [maintenance], but that is because the picture does not match reality, because we are too sloppy. (Operations Electrician)

Deliberate or not, "sloppiness" in reporting puts into question the validity of experts' suggested changes as they are based on analyses of an "incomplete dataset" (Operations Electrician). It shifts, albeit informally, some decision authority from experts to operations in relation to the how and when of equipment maintenance. This type of situated authority is considered important because things do not always go according to expert plans:

> There is a factor that is incredibly decisive, the unforeseen. The things that come up. From experience, we are talking about 30 % of resources that must go towards handling that. So, you can have a plan, but that can change overnight. (Union Leader)

As such, pre-planned maintenance programs are frequently overridden based on operations evocation of their situated authority. These silent "protests" are usually grounded on arguments about safety, much to the frustration of those that see it more as "politics to keep jobs" (Maintenance Operations Team Leader C). An analyst airs his frustration:

> Those out in the ocean are really just supposed to do as they are told. At least in theory. But if you change something that they have been doing for a long time you will get protests. If you want to increase the interval for maintenance on fire pumps [to cut maintenance hours and costs] then this all of a sudden becomes dangerous […] leading to less safety. (Maintenance Analyst I)

Incomplete data, then, spur "disagreements about who really decides" (Maintenance Expert Team Leader B) and makes salient a tension between planned authority of the experts and situated authority of operations.

4.2 Knowing Tensions

EnergyCo platforms are not standardized entities and, due to decades of operations, large parts of the production capital is old and worn. The diverse "platform portfolio" presents challenges to the organization because "[when] all platforms are different, it is no longer the same company in a sense." (Maintenance Expert Team Leader D) Maintenance programs naturally inherit the idiosyncrasies from the platform they are linked to:

> There are very individual considerations that are done when you establish programs. One platform has this philosophy, and another has that philosophy. (Maintenance Expert A)

Diversity in age and design emphasizes the importance of on-site maintenance work, a form of expertise which traditionally has been acquired through years of *experience* offshore. As situated in the particularities of a platform over time, operations gain intimate knowledge about equipment:

> To put it like this, when I talk to operational engineer Norvald, he has been the operations and maintenance manager on [Platform x] for many, many years. So, when you tell him about [a certain issue] he is on it right away. He knows. (Maintenance Operations Team Leader B)

The same perspective is also highlighted by individuals in the other actor groups:

> Clearly, those who are out there and have been there since the start of the platform are in possession of totally unique knowledge. And we would have been lost without those people and that platform specific knowledge. Because there are so many subtleties on these platforms, so many strange things they know about. (Predictive Maintenance Team Leader)

Even if the "know-how that is situated out in the organization" (Predictive Maintenance Team Leader) is important to keep platforms safe and operational, there are arguments for supplementing it increasingly with *representation-based* knowledge. Representations of data can add to the perception of the human eye, revealing what goes on "under the hood":

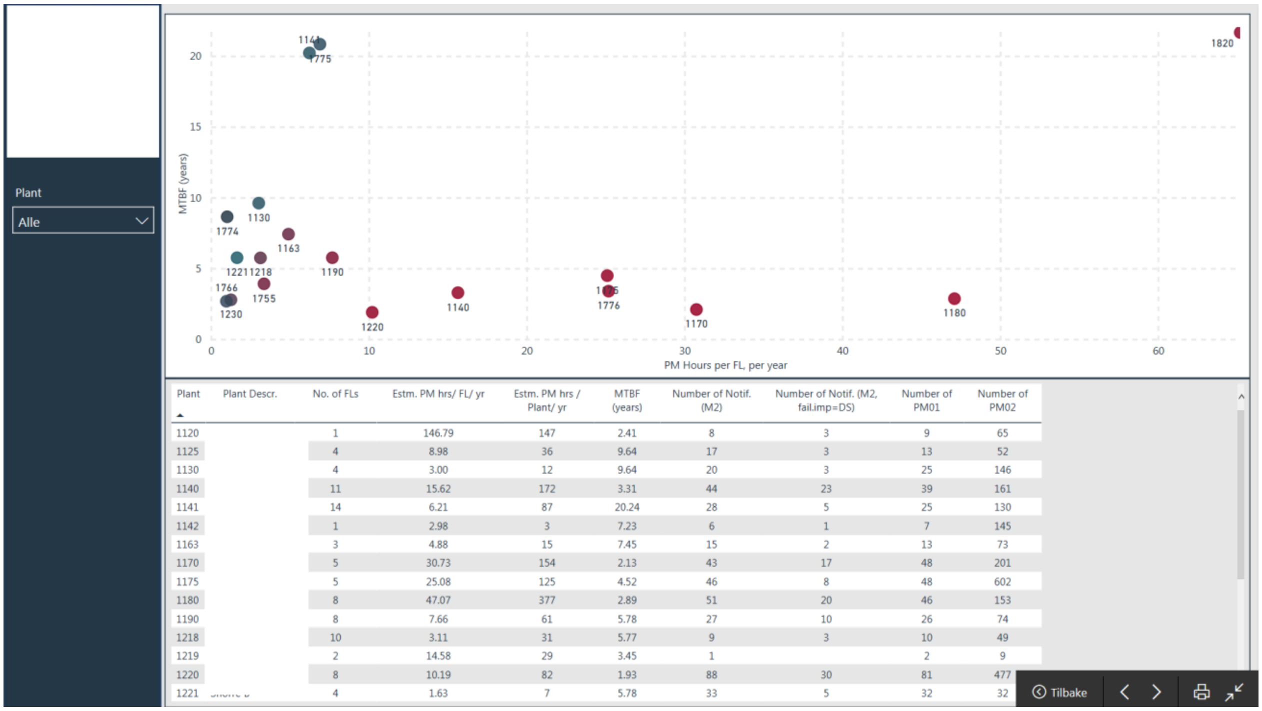
> Then we go in and look at the data [...] and we find out that it is usually the valve house that has corroded slightly on the outside. And you can just sand blow, paint, and then it is fixed. The valve itself is intact. Or that there are bolts that for example have rusted a little, and that has no impact on the safety related issues of the valve. (Maintenance Analyst H)

Moreover, representations of large datasets afford "learning across the organization" (Maintenance Expert Team Leader B); idiosyncratic platforms can adjust their maintenance practice in relation to 'best practice' in the population of platforms or equipment:

> It is difficult for a platform to make changes in the maintenance program and then monitor that. Because that takes a lot of time. So, here it is about utilizing big data and the wider company where we have 45 platforms with a lot of equipment. And because we have so large amounts [of data] we can quickly see if the decision was good or bad. (Maintenance Analyst D)

Maintenance Analyst D elaborates on a specific representation used in maintenance improvement work (Figure 8):

We have not been able to see this picture before, how each platform has performed in relation to reliability within an equipment group. [...] To see how the company performs across platforms and equipment groups, that is new. (Maintenance Analyst D)



Plant	Plant Descr.	No. of FLs	Estm. PM hrs/ FL/ yr	Estm. PM hrs / Plant/ yr	MTBF (years)	Number of Notif. (M2)	Number of Notif. (M2, fail.imp=DS)	Number of PM01	Number of PM02
1120		1	146.79	147	2.41	8	3	9	65
1125		4	8.98	36	9.64	17	3	13	52
1130		4	3.00	12	9.64	20	3	25	146
1140		11	15.62	172	3.31	44	23	39	161
1141		14	6.21	87	20.24	28	5	25	130
1142		1	2.98	3	7.23	6	1	7	145
1163		3	4.88	15	7.45	15	2	13	73
1170		5	30.73	154	2.13	43	17	48	201
1175		5	25.08	125	4.52	46	8	48	602
1180		8	47.07	377	2.89	51	20	46	153
1190		8	7.66	61	5.78	27	10	26	74
1218		10	3.11	31	5.77	9	3	10	49
1219		2	14.58	29	3.45	1		2	9
1220		8	10.19	82	1.93	88	30	81	477
1221	[illegible]	4	1.63	7	5.78	33	5	32	32

Figure 8 *Representation showing no correlation between maintenance hours and failure rate.*

In the visual representation, maintenance efficiency of EnergyCo platforms is plotted by comparing number of hours of preventive maintenance for specific equipment (x-axis) against mean time between failure of the same equipment (y-axis). The plot shows no linear relationship between hours allocated to predictive maintenance and mean time between equipment failures. One interpretation is that more maintenance does not lead to equipment failing less.

Such representations are by no means novel in EnergyCo. However, digitalization makes them proliferate. New forms of representations are envisioned to help "detect equipment with recurring failure" (Maintenance Analyst B), obtain "control over the condition of [equipment and] the system that you are to describe and handle integrity wise" (Maintenance Expert A), "show if there is potential for optimizing the test frequency [of equipment]" (Maintenance Analyst B), and ideally "make a picture that [is] able to tell us, preferably every quarter, that something is about to happen." (Maintenance Analyst D)

Representations like Figure 8 are considered valuable by personnel on the shop floor and top management alike. Hence, EnergyCo made two organizational changes especially geared towards producing them: establishment of the MAU in 2017 and the IOC in 2019. The MAU and DMVA project aim to utilize notifications to produce representations for enhancing equipment performance and optimize maintenance work. The IOC, and specifically the PMU, aims to utilize representations of data to predict equipment malfunctions. That is, where the MAU focuses on optimization through learning from history, the IOC/PMU focuses on predicting the future by detecting "abruptions before they occur" (SVP of Operations Technology):

> [IOC] consists of 17 so-called pods. These are advanced workstations where you have larger screens and also access to more data than you have at a regular workstation. The preventive maintenance unit has 14 of these pods [...] On a normal workday the engineers monitor equipment on a range of platforms. We monitor a large selection of sensors on [more than 40] platforms. (Predictive Maintenance Team Leader)

Not all platforms currently have the necessary sensors in place for real-time equipment monitoring. The implication is that sensors currently cannot provide a complete picture of offshore reality. However, EnergyCo's newest addition to their platform portfolio is a testament of a different future:

> [Platform y] is our operational and digital flagship [...] equipped with sensors [and with a] huge potential for implementing condition-based maintenance on more or less all equipment groups we know about. (Predictive Maintenance Team Leader)

With platforms like this, EnergyCo is "able to build [really] good pictures centrally" (Predictive Maintenance Team Leader) of equipment condition, potentially impacting maintenance practice severely. Moreover, future platforms will be designed after the blueprint of the digital flagship. EnergyCo is, in fact, radically rethinking platform design to align the physical with intentions of producing high-quality representations:

> In the long run, the big idea is that we can design platforms […] with a thought of a well-functioning center onshore in the back of our minds. A center that can actually execute maintenance for us onshore, digitally you know. That means you can build platforms with

> smaller living quarters, a completely different set of sensors and that are much more cost efficient to operate. (Predictive Maintenance Team Leader)

This outlook is echoed by people in operations, even though it is possibly located further into the future than the analysts and experts think:

> What we must admit is that the old platforms are built on concepts from 30-40 years ago. Much of the equipment is conservative and must be maintained in accordance with this. Therefore, you cannot just say that the world has developed with a lot of digital technology and believe that these things will sort themselves out. That is a distortion of reality. Even on the platforms built in the last few years, it is difficult to make digitalization happen fully. But it is clear that the day you are able to build an installation that is adapted to all of this [digital technology] you will get more return on these things. (Union Leader)

As such, EnergyCo maintenance is a process where experience-based and representational knowledge practices currently co-exist. There is, however, an organizational push towards the representational. This makes tensions between the knowledge practices manifest. In the words of the union leader: "It is those that have practical experience up against [the] engineers with their papers." (Union Leader)

4.3. Valuation Tensions

The valuation tension is rooted in different opinions about how to attain a well-performing organization: through valuing the efficiency of task rationalization made possible through data analytics, or through valuing the diligence of contingent and localized task performance by experienced offshore operators:

> You have to analyze your way to the right maintenance, what the optimal maintenance is in relation to the specific equipment. [That way we] simply get a more secure and better base to calculate what is right [...] The risk now is that we spend too many hours [doing unnecessary maintenance] rather than doing it in a better way. (Maintenance Expert Team Leader C)

> We want the same thing; we want what's best for the company [...] But we have […] different experiences and different opinions about what the right way forward is. [...] In my

> opinion it is incredibly important to have people [on the platforms]. [...] I 100% agree that we should [do] thorough analysis. Clearly, we should not do unnecessary maintenance. We should do the right maintenance at the right time. It is just that the [digital] tool is based on a lot of data, and very little experience. (Union Leader)

Digitalization of EnergyCo maintenance has intensified analytical work related to both historical notification data and real-time sensory data to “optimize” maintenance activities. The representations produced are ostensibly objective “facts” that are mobilized for efficiency purposes:

> [I]f we had a robot that […] adjusted based on facts and available data I believe we would have had a much more optimal and efficient program. (Maintenance Analyst I)

In Maintenance Analyst I’s opinion, there is a distinction between the imagined rational software robot and the politically motivated human actor. Humans, more precisely offshore operations personnel, seemingly fail to remain objective in light of the “facts”. Fear of downsizing, unwillingness to change and an exaggerated focus on safety clouds their vision:

> If [the digital representation] shows that mean time to failure for a valve is 150 years, then rhetoric about why you still need routine inspections and preventive maintenance should not trump facts. (Senior Performance Analyst)

Moreover, the advocates of task rationalization argue that “objective” representations (like Figure 8) show that more maintenance is sub-optimal and can sometimes be wrong:

> [P]eople should understand that more maintenance doesn’t necessarily yield better results, or that less maintenance yields worse results […] We have examples of the opposite [...] For example, lifeboat engines that have never been in the ocean were tested so much that they broke. It was of course with good intentions, “we have to test”, right, “see that they work”. But every time we tested them, they became a little worse, and in the end they broke down. (Maintenance Expert Team Leader B)

By trusting “objective” representation, maintenance can go from a state of “fixing ourselves to death” (Maintenance Operations Team Leader B) to doing “right maintenance at the right time with right effort”. (Maintenance Operations Team Leader C)

Arguments about the need for some objective “base” on which to recommend maintenance changes do not emerge out of thin air. We observed accusations and admittance about dubious notification reporting routines. In addition, critics claim that poor notification quality allow operations to deliberately build slack into maintenance programs:

> If you build in a lot of contingency or slack into your [reported] time estimate, you have some more time to do your work. (Maintenance Expert Team Leader D)

The accumulated result are “robust” and costly maintenance operations.

> [I]t might be the case that [maintenance programs are] way too robust, right. That [operations] have created more hours for themselves than what is necessary, to protect their own positions and jobs, right. So, it is good for them to be challenged on that, but it is important that they are heard also. (Maintenance Operations Team Leader B)

Arguments about political motivation underlying “robust” maintenance programs are used by certain analysts and experts to legitimize the value of “objective” and “fact-based” approaches to maintenance. However, operations people claim this is a reductionist argument. Maintenance programs are “robust” because representations can never incorporate all relevant information. Hence, the diligent operations worker contributes to the organization by “being sober in relation to what the analysis tells you” (Maintenance Expert A) and making sure that maintenance work is done “right” in relation to the idiosyncratic requirements of the local setting. Even analysts acknowledge that all representations leave out certain things that only local practices can “add”:

> [T]he dashboard does not show the whole picture. It shows a part of the picture [...] On the one hand you have some people that have put two lines under the answer and arrived at an action, and on the other hand you have those with expertise, that know that this is about much more than those variables in the formula. That can create tensions [between] technology and organization. How can the organization have trust in itself? That the data it

> has through digitalization doesn't cover it all, because there are several things that cannot be put into numbers. (Maintenance Analyst F)

Incomplete representations, operations argue, need to be "supplemented" with the experience of offshore operations to ensure safety and productivity. And, since experts and analysts rarely have offshore experience, operations are the only ones that can provide it. Their diligence is valuable "because reality lies out there, whichever way you twist and turn it." (Union Leader) The union leader continues:

> [I] simply believe that when you are sitting onshore you do not have the same feeling with the job. Those who are out [in the ocean] they have experience with it, they feel it on their body, they are there and have tight connections to it. And if [we get] people that, in a sense, do their job and at 2:30 they are at the kindergarten and pick up their kids and have their focus in another place, it will not be the same. (Union Leader)

The advocates for the value of diligent and localized task performance, then, worry about personnel being increasingly moved onshore. The concern is that safety standards will drop in parallel with transitioning towards task rationalization and efficiency. Although counterarguments about "no lives [being] lost if there are no people [out there]" (Predictive Maintenance Team Leader) are presented frequently, operations seem to believe that the presence of personnel offshore is crucial for safe operations:

> It is absolutely true that there are discussions about what's right and reasonable and sound from a safety perspective. There are very different opinions between what the engineer wants to do and what the executing [team offshore] want to do. (Maintenance Expert Team Leader B)

The tension between valuing efficiency of task rationalization and valuing diligence of contingent and localized task performance is tied to authority and knowing tensions. Although the divide between onshore experts and analysts and offshore operations should not be viewed as constantly conflict-ridden, such tensions between the groups are explicitly acknowledged:

> Most [experts and analysts] have barely set foot on a platform […] Their arguments are not based on facts. They're based on subjective opinions, unfortunately. (Operations Electrician)

5. Discussion

While digitalizing knowledge work has been repeatedly shown to benefit organizations, individual workers, and the economy at large (Wagner et al., 2021), scholars recognize that digitalization can simultaneously lead to unintended consequences (Newell & Marabelli, 2015). Our work contributes to this discourse by theorizing digitalizing knowledge work not simply as a linear process with dichotomous outcomes, but as a paradoxical process of multiple interacting tensions. In the following, we discuss this contribution in three steps. First, our case study demonstrates how digitalizing knowledge work in EnergyCo engendered manifestations of authority, knowing, and valuation tensions. These findings corroborate existing research on how digitalization is displacing or reconfiguring existing ways of doing knowledge work (Monteiro & Parmiggiani, 2019; Pachidi et al., 2020; Orlikowski & Scott, 2014) and they contribute new insights by showing how digitalization trajectories are shaped as salient tensions are constructed, mutually influence, and accentuate each other. Second, by theorizing the social construction of tensions and responses to these tensions, we unearth how the totality of the interacting tensions and responses make digitalizing knowledge work inherently paradoxical. Finally, we discuss how digitalizing knowledge work as a paradoxical process impels unintended consequence of digitalization that may lead to further spirals of unintended consequences contingent on organizational responses.

5.1. The Construction of Tensions in Digitalizing Knowledge Work

Of the three identified tensions in digitalizing knowledge work, the tension between experience-based and representation-based knowing has received most attention in existing literature (Faraj et al., 2018; Pachidi et al., 2020). This tension is typically portrayed as polarizing, implying conflict between the elements, as favoring one will overshadow the other (Bosserman, 1995). The opposites represent distinct ways of knowing, and through progressive digitalization, representation-based knowing is – for better or worse – reported to supplant experience-based knowing (Constantiou & Kallinikos, 2015a; Davenport, 2018; Pachidi et al., 2020; Zuboff, 1988; 2019). Through rapid developments in data-generating and sensory technologies and analytical techniques that generate representations from these data (Monteiro & Parmiggiani, 2019), the polarization of knowledge work arguably becomes increasingly amplified. Our review of literature on tensions in knowledge work, however, shows that digitalization also frequently incurs authority and valuation tensions. We expand this work by demonstrating how the interactions between these three tensions and the organizational responses they elicit engenders a non-linear and contextually contingent digitalization process.

Drawing on dialectical inquiry (Benson, 1977; Cho et al., 2007; Putnam, 2015) and the conceptualization of dialectic relationships as either complementary, mutually implicating, or polarizing (Bosserman, 1995; Lindgren et al., 2021), we propose a model (Figure 2) for explaining how tensions are constructed in the digitalization of knowledge work. Our model shows how digitalization can *trigger* the construction of salient tensions in authority, knowing, and valuation in knowledge work. This, in turn, *shapes* sociomaterial responses, that recursively *reinforces* how tensions are constructed, which eventually *transforms* the digitalization of knowledge work. We draw on the dialectics of tensions in EnergyCo to warrant and expound our model and its workings.

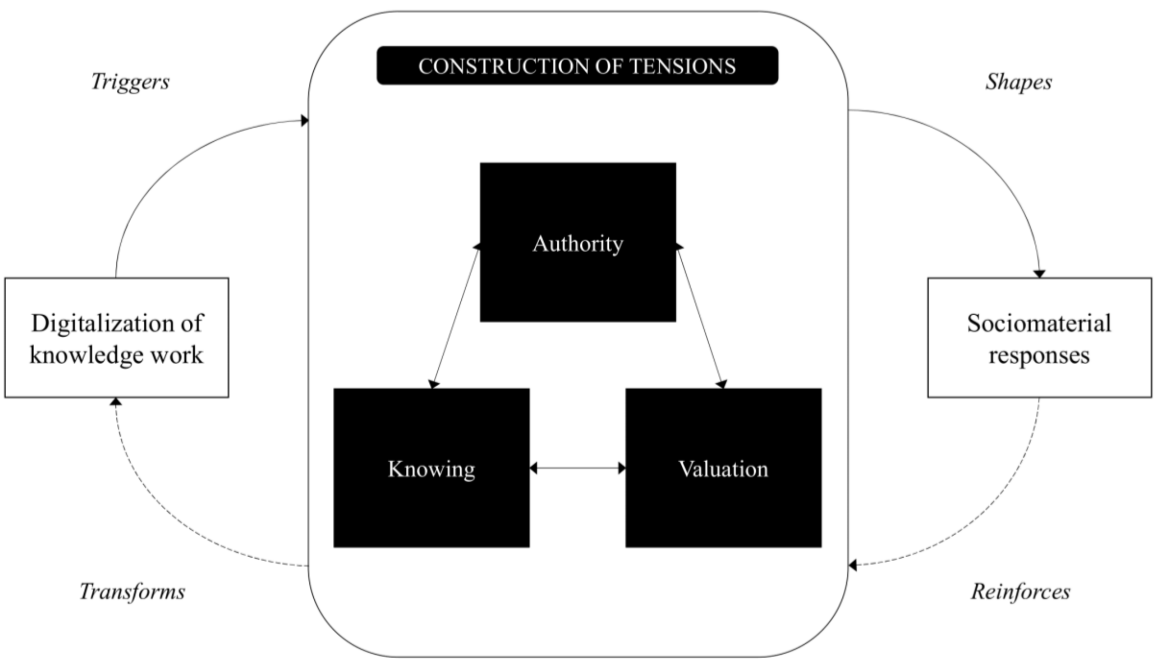


Figure 9 *Process model of the construction of tensions in digitalizing knowledge work.*

The implementation of EnergyCo's strategy to digitalize knowledge work within machine maintenance includes multiple characteristics shown to trigger the construction of salient tensions: plurality of perspectives (e.g., between different roles in the maintenance loop), scarcity of resources (e.g., digitalization as a means for organizational efficiency), and rapid change (implementation of new technologies over a relatively short time span) (Lindgren et al., 2021; Smith & Lewis, 2011). Digitalizing work in EnergyCo, however, not only triggered authority, knowing, and valuation tensions, but also shaped the contextual processes of constructing the opposites and their dialectic relationships and the interrelationships between these dialectics. We explicate through some empirical examples.

The reported empirical evidence, for instance, shows that the dialectic relationship in the authority tension between planned and situated authority is predominately constructed as complimentary, while the knowing tension between experience-based and representation-based practices is predominately constructed as mutually influencing. Even though formal authority arrangements explicitly state that onshore experts "own" (Maintenance Expert Team Leader B) maintenance programs, authority is distributed across centralized and decentralized actors in practice. Furthermore, both representation-based and experience-based knowing are recognized as mutually important for performing maintenance. Digitalization incurs no explicit change in formal authority arrangements that entails that onshore analysts and experts now outrank offshore operators, or that representation-based knowing should completely supersede experience-based knowing. On the contrary, offshore operations are still allowed and encouraged to exert judgment in maintenance. In the current environment – where an array of EnergyCo platforms are not equipped with sensors – they possess "totally unique knowledge" about offshore conditions that the organization would be "lost without" (Predictive Maintenance Team Leader). In other words, the authority tension between planned authority that is embedded in the task organization and situated authority that emerges during task performance is constructed as mutually influencing. This mutuality in authority enables mutuality in knowing, in that strengthening one form of knowing also strengthens the other.

Simultaneously, however, the organization responds to the valuation tension by prioritizing efficiency of task performance. The MAU and the PMU promoting representation-based knowing for "optimal" maintenance (Maintenance Expert Team Leader C) are added to the organizational landscape together with substantial funding allocated to these units as part of the digitalization strategy. Moreover, the newest additions to the EnergyCo platform portfolio are equipped with all the sensors needed for condition-based maintenance. The relative importance, therefore, of experience-based practices is challenged, even without explicit change in formal authority arrangements. As digitalization engenders emergence and dissemination of representations, it becomes more difficult for operations to argue against “facts” that “show” maintenance as inefficient (Senior Performance Analyst). At the very least, offshore knowledge should be “challenge[d]” (Maintenance Analyst I) by objective data to ensure that “politics” (Maintenance Operations Team Leader C) do not become an impediment to rational and cost-efficient operations. The organization, therefore, manifests a polarization in the valuation tension between the rational and efficient knowledge lodged onshore, and contingent and localized task performance offshore. Representation-based knowing is constructed to support the former, weakening the relative position of experience-based knowing in the process.

Increased representation-based knowledge, then, prepares the ground for shifts in future authority arrangements. If the platform portfolio develops towards including more sensors as old platforms are substituted for “digital flagships” (Predictive Maintenance Team Leader) there will be less need for experience-based expertise. Even representatives from operations see this as a plausible future. It is seemingly only a question of time before digital technology can come to represent offshore realities accurately. Adding sensors will enable the building of more high-resolution “pictures” (Maintenance Analyst D), and planned authority can become more secure in its predictions. As a result, there will be less need for situated and diligent operators exerting judgements. Authority, knowing, and valuation tensions are all intermingling and shaping the trajectory of the maintenance operations future. The response to the valuation tension pushes it towards polarization, where digitalization will lead to representation-based knowledge eventually substituting experience-based knowledge.

Dialectical theory emphasizes how the recursive clash between opposites can lead to their co-development without necessarily bringing about a new synthetic form (Farjoun, 2016). Our model elaborates on the logic of such recursive clashes by suggesting that the social construction of salient tensions shapes sociomaterial responses. By considering the interactions between tensions, we get a deeper understanding of the particularities of the general model. The materialization of new ways of performing knowledge work – in the form of new organizational structures, novel digital technology for data analysis and visualization, and changes in offshore platform designs – in turn objectifies the contradictions that we have shown to manifest. This is particularly made visible through increasing valuation of efficiency and dissemination of representation-based knowing that, at least informally, increasingly shifts authority in task performance to the onshore community. As such, this dialectical process shows how "socially constructed contradictions can 'harden' into seemingly objective structures, which then influence but do not determine social construction processes" (Hargrave, 2021).

5.2. The Paradox of Digitalizing Knowledge Work

The empirical material alludes to proponents of a certain way of knowing tending to evaluate their own knowing practices as more fit to the task than alternative ones. Many analysts and experts argue that experience-based knowing is entrenched by organizational inertia and internal politics. Increased reliance on representation-based knowing is, in their view, crucial in terms of valuation and authority, as it enables more efficient task performance through rationalization and more centralized and holistic planning. By overcoming the inertia of experience, a more rational way of doing knowledge work can be achieved.

Offshore operations, in contrast, argue that lack of hands-on experience and overreliance on reductive models provides incomplete knowledge. They view onshore analysts and experts as decoupled from "reality […] out there" (Union Leader). In their view, knowledge of machinery necessitates some physical experience with it, preferably over long stretches of time. This view is accentuated by the high-risk environment they operate in, as faulty machinery can result in costly downtime as well as high-impacting environmental and personal safety incidents. Following this perspective, it is crucial that the authority and valuation tensions do not engender diminishing operational presence offshore. However, there is simultaneously a view of many individuals in all actor groups that the two forms of knowing need to be balanced. There is an experienced need for modernizing maintenance practices through representation-based knowing, while at the same time preserving operations' experience-based knowing.

The organizational establishment of the MAU in 2017 and the PMU in 2019 shows how this contradiction – needing the intimate machine knowledge of operations but simultaneously diminishing their organizational presence – becomes further materialized through organizational responses over time. The units are established and heavily funded, and these changes in organizational arrangements reinforce the valuation and legitimacy of representation-based knowledge. However, their practices also make evident the lack of good-quality data due to dubious reporting routines and old equipment with shortage of sensors. Representation-based knowing, in turn, is not completely trustworthy. The suggested remedy is to equip future platforms with increasingly large sensory sets, subsequently leading to decreased need for offshore operations to produce low-quality notification data. Such ongoing sociomaterial responses, then, can further polarize tensions triggered by digitalizing knowledge work.

As a totality – viewing the perceptions and activities of different groups and individuals together – the dialectic relationships between opposites are simultaneously mutually influencing and polarizing. This creates a paradox, as increasing available data to improve task performance through digitalizing knowledge work can simultaneously decrease the capability to perform the task effectively. Articulated as such, we see how digitalizing knowledge work is constituted by tensions that have "contradictory yet interrelated elements that seem logical in isolation but absurd and irrational when appearing simultaneously" (Lewis, 2000, p. 760). Increased use of data leads to increasing reliance on representation-based knowing in maintenance, rationalized and efficient task-performance, and centralized authority deciding in maintenance. At the same time, experience-based knowing and localized task performance provides contextual and specific insights that are crucial for safe and situation-specific operations.

Paradoxes can by definition not be solved by favoring one polarity over the other (Smith & Lewis, 2011). Rather, they need to be balanced over time (Brooks et al., 2020). However, we see tendencies in EnergyCo of constructing relationships in the authority, knowing and valuation tensions as polarized. The case shows how a shift in knowing practices is driven by a management-led digitalization strategy, with the valuation of increased efficiency in task performance as its dominant goal. As such, representation-based knowing is, even before implementation, imbued with authority and valuation schemes that position centralized, quantified, and rational decision-making as an integral part of what digitalization entails. Scholars warn that responding to paradoxes through suppressing one polar of a paradoxical tension can lead to vicious cycles of manifestations and responses that result in single-focused and short-term orientations that suppress alternative perspectives (Smith & Lewis, 2011). The paradox of digitalizing knowledge work can, in other words, lead to self-reinforcing cycles of polarization of knowledge work with ramifications we do not know the consequences of.

5.3. The Unintended Consequences of Digitalizing Knowledge Work

Digitalizing knowledge work is shown to produce beneficial consequences for organizations, individual workers, and the economy at large (Wagner et al., 2021). Scholars have contributed significantly to our common understanding of how digitalizing knowledge work leads to new types of tasks and new ways to cooperate (Mikalsen & Monteiro, 2021; Wang et al., 2020), enabling digital transformation of organizations (Vial, 2018). However, scholars have also long recognized that digitalization can lead to unintended consequences (Newell & Marabelli, 2015). As numerous studies of digitalization have shown, knowledge workers do not necessarily use digital technologies as intended by designers or implementers, leading to workarounds and emergent activity patterns in organizations (Berente et al., 2019; Ejnefjäll & Ågerfalk, 2019; Markus, 1994; Wimelius et al., 2021). Such unintended consequences of digitalization might seem trivial, but can potentially be harmful, leading to increased individual stress through use of digital technology in work tasks (Ayyagari et al., 2011), blurring of the work-life balance (Wang et al., 2020), or monopolization of power and authority as a consequence of the generative potential of platforms (Zuboff, 2019). More directly related to this investigation, the current wave of digitalization – intensified by the implementation of AI-enabled technologies (Berente et al., 2021) – has been reported to lead to knowledge workers losing expertise and critical thinking skills (Mayer et al., 2020).

In this research, we contribute to the literature on unintended consequences of digitalizing knowledge work by revealing how digitalization processes involve several conflicting forces that shape its trajectory. Our dialectical analysis demonstrates how digitalizing of knowledge work in complex organizations is a non-linear process that leads to unintended consequences as it makes inherent oppositions between different ways of performing knowledge work salient. The recursive processes that underlie this construction of tensions did, in the EnergyCo case, manifest as a paradox. Our theoretical foundation prescribes that in a paradox, the tensions between poles must be continuously balanced (Smith & Lewis, 2011) or risk vicious cycles of polarization where one pole is suppressed. Our process model of how this paradox becomes constructed explains that the dynamics of polarization was already latent in the case under study. What polarization of knowledge work generally entails, however, is highly uncertain.

While both researchers and practitioners argue for more quantitatively driven and representation-based decision making (Davenport, 2018), there is a growing concern that relying solely on statistical modeling of historical data can make practitioners less capable of handling so-called ‘unknown unknowns’, events that are highly challenging or impossible to predict based on discernable patterns in data (Kay & King, 2020). Decision making under radical uncertainty requires experienced experts who can assess representation-based predictions as inputs to decision making (Kay & King, 2020). Our dialectical inquiry, however, makes us conclude that we do not know the consequences of digitalizing knowledge work when it comes to the relative weakening of experience-based knowing. In many settings, centralized task authority, representation-based knowing, and valuing the efficiency of rationalized task execution is clearly beneficial (Wagner et al., 2021). In organizational settings like EnergyCo, however, which constitutes an extreme case in terms of safety requirements, knowing how unintended consequences unfold is particularly important. It may be that a shift to representation-based ways of knowing is beneficial in such contexts’, but it may also be detrimental. If we solely evaluate ways of knowing based on their own evaluation criteria, i.e. that representation-based maintenance is more ‘objective’ because it is based on quantitative data and analytical techniques, we may lose important insight and practices.

The perils associated with reconfiguring knowing in work through digitalization become more salient when its future consequences are taken into consideration. Østerlie and Monteiro (2020) show how making data organizationally real – i.e., having effects in the organization – requires substantial alterations in existing knowledge practices. In our case, as data becomes organizationally real, it also becomes materially real, in the sense that the organizational and material arrangements of knowledge and tasks are changed as the organization is becoming increasingly representation-based. The future design of offshore production platforms will be engendered by concerns for automation, sensor-based knowledge, and centralized task authority. The offshore platforms are, in other words, physically redesigned to accommodate a ‘world of data’, with seemingly less room for situated decisions by people that practice experience-based knowledge. The effects of this shift are yet to be revealed.

We do not know the long-term consequences of paradoxes that are constructed through the digitalization of knowledge work. As the digital transformation of society continues, a plausible development is, however, loss of experience-based knowing. Evidence from our case study supports such a claim. We see tensions between polarities of authority, knowing, and valuation, and our analysis shows that representation-based knowing becomes materialized because of its relation to digitalization strategies and agendas. Experience-based practitioners argue that data-driven knowing is insufficient, but there is a danger that such voices are not given room in the narratives we as researchers partake in constructing. They are quickly discarded as 'out of date' and frequently reduced to merely annoying political obstacles in the way of technological advancement. This reminds us that we as researchers are accountable for our theories and the world it dialectically partakes in constructing (Schultze et al., 2020).

6. Conclusion

Our dialectical inquiry into digitalizing knowledge work provides important contributions to the literature on the unintended consequences of digitalization. By reviewing the literature through a dialectical lens (Benson, 1977; Hargrave, 2021) and recent scholarship on contestations in knowledge work (Pachidi et al., 2020), we elaborate existing literature on digitalizing knowledge work by showing that it involves three latent tensions of authority, knowing, and valuation. Through a dialectical inquiry into the EnergyCo case, we show how these tensions were constructed and manifested. As a result, we contribute a process model of digitalizing knowledge work to the literature, in which we show how these three types of tensions interact and shape digitalization trajectories through sociomaterial responses. Practically, the model can help managers to grasp the non-linearity of digitalization processes and to understand that digitalizing knowledge work triggers multiple interacting tensions that can lead to paradoxical processes that are challenging to navigate.

Our study has limitations. It is based on a single qualitative case study with certain limits to generalizability and validity (Yin, 2013). As such, transfer of our findings to other contexts requires additional research. Our review of literature was also conditioned by Pachidi et al.'s (2020) perspectives on knowing. Expanding this framing would probably have revealed other relevant tensions than the three we identified. We, therefore, hope that our work will inspire and provide a scaffold for further investigations into the tensions and paradoxes of digitalizing knowledge work.

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8. Appendix

Table 8 *Interviews*

#	*Role*	*Date*	*Round*	*hh:mm*	*Recorded*
1	Senior Performance Analyst	13/03/19	1	02:00	N
2	Financial Maintenance Controller	20/03/19	1	00:56	Y
3	External Maintenance Consultants	09/04/19	1	02:00	N
4	Senior Maintenance Engineer A and Safety Representative	11/04/19	1	01:00	N

5	Senior Performance Analyst, Maintenance Analysts Team Leader and Maintenance Analyst A	11/04/19	1	01:30	N
6	Maintenance Operations Engineer A	12/04/19	1	00:50	Y
7	Maintenance Operations Engineer B	25/04/19	1	00:53	Y
8	Senior Maintenance Engineer A	30/04/19	1	01:00	N
	Total of eight interviews in Round 1				
9	Maintenance Analyst A	14/10/19	2	01:00	N
10	Maintenance Analyst B	16/10/19	2	01:05	Y
11	Data Governance Manager	16/10/19	2	01:00	N
12	Maintenance Analyst C	16/10/19	2	00:55	Y
13	Maintenance Analyst D	17/10/19	2	00:53	Y
14	Senior Performance Analyst A	21/10/19	2	01:45	N
15	Maintenance Analyst E	22/10/19	2	01:00	N
16	Maintenance Analyst F	23/10/19	2	01:16	Y
17	Maintenance Analyst G	23/10/19	2	01:20	N
18	Maintenance Analyst H	23/10/19	2	01:04	Y
19	Maintenance Analyst I	24/10/19	2	00:58	Y
20	Maintenance Analysts Team Leader	25/10/19	2	01:00	N
21	Maintenance Expert Team Leader A	28/10/19	2	00:39	Y
22	Maintenance Expert Team Leader B	29/10/19	2	00:41	Y
23	Integrated Operations Center Leader	30/10/19	2	00:45	N
24	Maintenance Operations Team Leader A	31/10/19	2	00:56	Y
	Total of 16 interviews in Round 2				
25	Maintenance Analysts Team Leader	14/02/20	3	01:38	Y

26	Maintenance Expert Team Leader C	11/06/20	3	00:43	Y
27	Maintenance Expert A	17/06/20	3	00:37	Y
28	Maintenance Expert Team Leader D	18/06/20	3	00:58	Y
29	Maintenance Operations Team Leader B	13/08/20	3	01:03	Y
30	Union Leader	21/08/20	3	00:56	Y
31	Operations Electrician	31/08/20	3	01:19	Y
32	Maintenance Operations Team Leader C	04/09/20	3	01:03	Y
33	Maintenance Analysts Team Leader	11/09/20	3	00:30	N
34	Predictive Maintenance Team Leader	12/01/21	3	01:00	Y
35	Predictive Maintenance Analyst	12/01/21	3	00:56	Y
36	Maintenance Analyst D	14/01/21	3	00:57	Y
37	Maintenance Analyst J	14/01/21	3	01:01	Y
38	Maintenance Analysts Team Leader	28/01/21	3	00:35	Y
39	Maintenance Analyst D	22/09/21	3	00:16	Y
40	Maintenance Expert B	29/09/21	3	01:25	Y
	Total of 16 interviews in Round 3				

Table 9 *Selection of retrieved documents*

#	*Content*	*Retrieved*
1	Presentation slides about new digital architecture and new digital opportunities for energy production	06/11/2020
2	Article about launch of digital strategy with interviews of CEO and COO	26/11/2020
3	Presentation slides of EnergyCo's technology strategy	26/11/2020
4	Article about how digitalization is changing EnergyCo with interviews of two employees and CDO	23/04/2021

5	Article about purpose of new digital architecture by CIO in EnergyCo	23/04/2021
6	Article about launch of IOC center with interviews of top management, including SVP of Op Tech	04/05/2021
7	EnergyCo corporate presentation	20/05/2021

Table 10 Data structure connecting empirical material, first-order and second-order concepts.

Empirical examples	***First order***	***Second order***
If you want to call using data tools in general, everything that goes into that 'digitalization' word, it is of course so that it can both make us more effective and safer. Definitively. There are after all enormous volumes of data that we can use, and the potential for learning across our organization […] is huge. (Maintenance Expert Team Leader B) At the same time, when we have tested 45 000 gas detectors and only one had a fault, we probably don't need to test 45 000 next year as well. The one guy that found the faulty gas detector might think differently, and that might be ok. [...] But this is what the analyses can help us with, how things really are, and use the information we have when we are to decide. (Maintenance Expert Team Leader B) We wanted to make a picture that was able to tell us, preferably every quarter, that something is about to happen. (Maintenance Analyst D)	Maintenance work through doing analyses and suggesting improvements	Knowing tensions
They have maybe been there for 20 years and know the equipment and know exactly how that equipment is and if they spend a lot of time on it and if there are a lot of faults on it etc. So, we want them on that journey and to contribute with what they know. (Maintenance Operations Team Leader C) A lot of them have competence, informal competence, they are really skilled and have a lot of experience in our operation. So, they are skilled. (Maintenance Expert A) To put it like this, when I talk to operational engineer Norvald, he has been operations and maintenance manager on [Platform A] for many, many years earlier so when you tell him about [a certain issue] he is on right away. He knows. (Maintenance Operations Team Leader B)	Maintenance work through being at the platform	
That is something we do the most with, to get people to think 'is this something we can monitor or do we have to fix it straight away?' The culture in the industry is to fix it right away. (Maintenance Operations Team Leader C) [The people in operations say] 'I want to test the equipment every day,' but it's not certain that that is a good idea. But if people come and ask 'is it necessary' [then they say] yes, I prefer to do it like we have always done it because it has gone well in the past. So, this is a lot about gut feeling and uncertainty. (Maintenance Analyst I) We actually have double up today. You would think that with all the sensors we have and all we	Tensions between approaches to doing maintenance	

can see you could have skipped a good part of the preventive maintenance. Because we after all have very good control on a lot of things. But we don't skip it. We have the classic calendar based preventive maintenance program as a base, and then we add additional monitoring to that. (Predictive Maintenance Team Leader)		
[Our analytical tool] is designed to present the facts, objective data and analyses which is to disarm empty rhetoric from the union or offshore workers. […] For example, if [our tool] shows that mean time to failure for a valve is 150 years then rhetoric about why you still need routine inspections and preventive maintenance should not trump facts. (Senior Performance Analyst, from field notes during demonstration meeting) You have to analyze your way to the right maintenance, what the optimal maintenance is in relation to the specific equipment. (Maintenance Expert Team Leader C) Let me say it like this, if we had a [software] robot that [automatically adjusted the maintenance programs] we would have had a much more correct program. Had the robot adjusted based on facts and available data I believe we would have had a much more optimal and efficient program. (Maintenance Analyst I)	Right maintenance is defined through analysis of objective data.	Valuation tensions
Well integrity is its own expertise anyway, with its own set of problems that you have to understand, because the dashboard does not show the whole image. It shows a part of the image. (Maintenance Analyst F) [I] simply believe that when you are sitting onshore you do not have the same 'feeling' with the job. Those who are out [in the ocean] they have experience with it, they feel it on their body, they are there and have tight connections to it. (Union Leader) Human assessment has to be done regardless and then they have to know about quite a bit of particular things on particular systems and know that there are some rules for these particular systems that makes it so that the [maintenance] interval never can be more than 24 months for example. Whilst in other systems the interval can go up to maximum 40, for example. (Maintenance Analyst H)	Right maintenance is defined through experience and local knowledge.	
I think we fix ourselves to death, right. We overhaul valves, screw on valves and sin plainly and simply with maintenance. (Maintenance Operations Team Leader B) It can be in your own unit, and then you can be heavily confronted with arguments about effective maintenance not being about analyses and what you can extract from a [digital tool]. It is actually about keeping the platform operational. They are very service minded, so when the platform calls them and says 'we have a problem,' they solve that problem and don't really care so much about cost. (Maintenance Expert Team Leader D) Yes, and just to clarify, I 100% agree that we should do that. Making a thorough analysis, I support that 100%. Because, it is clear that we should not do unnecessary maintenance. We should do the right maintenance at the right time. It is just that the [digital] tool is based on a lot of data, and very little experience. (Union Leader)	Tensions between interpretations about how to arrive at 'correct' maintenance work.	
The maintenance programs are owned by the expert leaders. They are to know what kind of grease that is to be used for a valve and how often it is to be applied. They are experts in [their field] and they are the ones that are to have an opinion about this. (Maintenance Expert Team Leader B) The experts really just own the technical content in a project, relating to what you need to do in	Experts decide when and what type of changes that are to be made to maintenance programs.	Authority tensions

order to preserve the integrity of the equipment. They are not following up whether operations are complying or not. That lies in the line. To follow up that they do the things that are agreed upon has nothing to do with the expert leaders responsibility. (Maintenance Expert Team Leader A) **But it is onshore, to put it like that, that has the final word in relation to changes [of maintenance], right?** Yes. (Maintenance Expert A)		
But it is also clear that those who execute the maintenance play an important role by reporting back about how the maintenance works. Then you can correct the program. But the ones that decide on changes in the program are the experts. (Maintenance Expert Team Leader B) Within the electrical expertise they have an expert leader, but the execution [of maintenance] they are not responsible for. The platforms themselves are responsible for this. (Maintenance Expert Team Leader C)	Offshore operations are important because they execute the maintenance and report on their work	
We suggest a maintenance regime based on what we have experienced so far. Each specific platform executes their maintenance and sends back reports on that. We analyze those and can then say something about whether we must do more, or if we can do less, or do something differently. (Maintenance Analyst D) We are trying to visualize and use the new tools that have come in the last few years. We try to automate data extraction and visualization. [...] The experts are responsible for making a final decision regarding whether an [maintenance] interval is to go up, down or remain the same. [Our job] is to give a recommendation through making data available. [...] Our [tools are] an aid in identifying candidates for improvement. (Maintenance Analyst B)	Analysts are responsible for analyzing the notification data, visualizing it and presenting recommendations to changes in maintenance.	
You get some disagreements from time to time about who really decides. (Maintenance Expert Team Leader B) It is supposed to be a collaboration, but you have to be certain that we get the professional experience into the judgements that are done. When the experts say that a valve can be greased every two years instead of every year, the offshore guy of course has to have a voice as well. [...] but someone has to decide. **And on paper that is the expert?** Yes. (Maintenance Expert Team Leader B) I think in the future we have to think more integrated solutions, where we put monitoring resources and expert resources together with maintenance management resources so that we have a group that has, in a way, a group of equipment as their responsibility, have great authority in deciding how maintenance is to be on the platforms, when it is to be done and what needs to be done. When are we going to say that the digital is good enough? I think that we will see more integration of different expertise internally in the company, that they get closer together over time. But it's like looking into the crystal ball, we have to see how the company develops, it's going to be exciting to follow. (Predictive Maintenance Team Leader)	Tensions in relation to who should decide what to do in relation to maintenance in certain situations and locations.	