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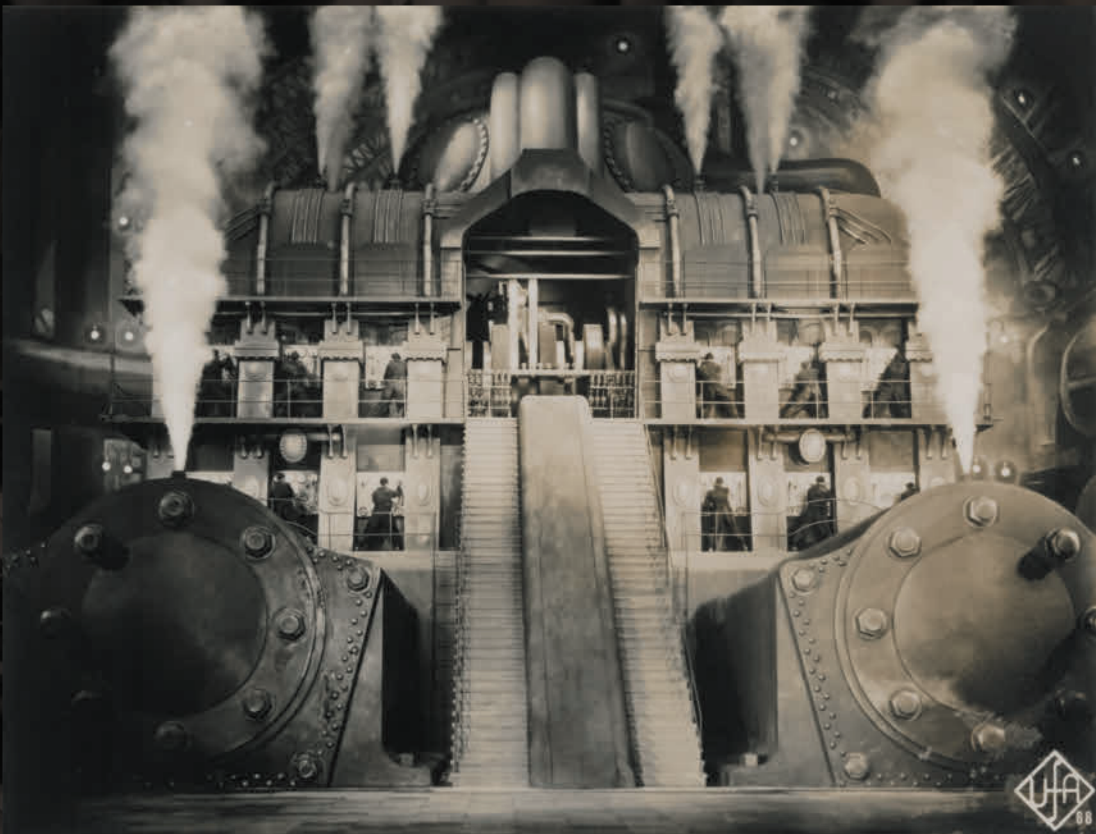

PERFORMING CONTINUITY OF/IN SMART INFRASTRUCTURE:

Exploring Entanglements of Infrastructure and Actions

Marko Niemimaa

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– To my best friend, mentor, close colleague, and beloved wife, Elina –

ABSTRACT

Nearly everything we do in contemporary organizations and societies builds on some form of infrastructure. Our reliance on infrastructures underscores the importance of the continuity of these infrastructures. However, the infrastructures are inherently unreliable and unpredictable and achieve veneers of permanence and stability only through constant and ongoing efforts. In their functioning, they become established through complex and uncertain processes that involve a number of actors and factors. Consequently, understanding those processes is a key concern for organizations that are responsible for these infrastructures.

Traditionally, the literature on the business continuity of organizational functions has emphasized the importance of planning and management approaches. Practitioners and academics have brought forth frameworks to aid organizations in planning and managing their continuity-related issues. The frameworks offer universally applicable processes and procedures that organizations should follow to improve their continuity. However, these frameworks tell little about continuity itself. Organizations rarely function as they document or as management describes organizational work. As such, the complex and uncertain processes of continuity cannot be directly inferred from the documents or from the managerial descriptions of work. If we wish to enact meaningful changes to those complex and uncertain processes through which infrastructure continuity becomes established, we need to understand how those processes unfold in practice.

This dissertation focuses on infrastructure continuity in a smart infrastructure context. Smart infrastructures are traditional infrastructures that have been extended with digital technologies. In this research, infrastructure continuity is approached from the perspective of technicians working in the smart infrastructure context. The technicians' work in these contexts is constitutively entangled with information systems and the technologies that form the infrastructures. As such, the smart infrastructures form an intriguing and fruitful yet rather unexplored context for information systems research. Theoretically, this research builds on sociomaterial theorizing and especially on Karen Barad's agential realism. The purpose of this dissertation is to increase understanding on how the continuity of smart infrastructure becomes performed. This purpose is explored through six research articles that form the foundations of this dissertation.

Methodologically, this research builds on conceptual and empirical research approaches. The conceptual research focuses on developing and clarifying business

continuity- and sociomateriality-related concepts and approaches through argumentation and a literature review. The empirical research builds on a qualitative research approach and, more specifically, on ethnographic research. As is typical for ethnographic research, the empirical material was collected from a single organization that was studied extensively over a several-month participant observation. Reflecting the purpose of the study, the ethnography was conducted in a centralized operations center of a smart infrastructure (smart power grid) where technicians work with information systems and technologies.

This dissertation contributes to the literature on infrastructure continuity and on sociomateriality. The primary contribution to the infrastructure continuity literature is a performative conceptualization of the infrastructure continuity. This conceptualization suggests that business continuity is not an attribute of any single measure but is an outcome of a joint accomplishment of sociomaterial networks of agencies that becomes established through recurrent actions. As such, the findings of this research challenge some of the taken-for-granted assumptions embedded in the literature but also extend the earlier literature. In addition, this dissertation extends discussions on sociomaterial agency. In the light of the findings, when agency is situated in the context of a smart infrastructure, agency becomes historic, polycentric, dynamic, and discontinuous.

TIIVISTELMÄ

Lähes kaikki mitä me teemme nyky-yhteiskunnassa nojaa infrastruktuureihin. Voimmekin sanoa elävämme keskellä infrastruktuurien verkostoa. Riippuvaisuutemme infrastruktuureista korostaa niiden toiminnan jatkuvuuden tärkeyttä. Nämä infrastruktuurit ovat kuitenkin perustaltaan epäluotettavia ja arvaamattomia. Niiden toimivuus syntyy monimutkaisten ja epävarmojen prosessien kautta, jotka sisältävät moninaisia toimijoita ja tekijöitä. Näiden prosessien ymmärtäminen on keskeistä organisaatioille, jotka vastaavat näistä infrastruktuureista.

Perinteisesti kirjallisuudessa, joka keskittyy toiminnan jatkuvuuteen (eng. business continuity), on korostettu suunnitelmien ja hallinnoinnin merkitystä. Suunnitteluun ja hallinnointiin on kehitetty useita johtamisen viitekehyksiä. Ne tarjoavat universaaleiksi tarkoitettuja määrämuotoisia prosesseja ja menettelytapoja, joita organisaatioiden tulisi noudattaa. Nämä viitekehykset kertovat kuitenkin hyvin vähän siitä mitä tai miten toiminnan jatkuvuus itsessään käytännössä ilmenee. Organisaatiot harvoin toimivat kuten dokumentoivat tai kuten organisaatioiden johto kuvailee toimintaa, joten näistä ei voida suoraan päätellä organisaation toimintaa. Kuitenkin jos haluamme toteuttaa merkityksellisiä muutoksia niihin monimutkaisiin ja epävarmoihin prosesseihin, joiden kautta toiminnan jatkuvuus syntyy, meidän tulee ymmärtää paremmin näitä prosesseja käytännössä.

Tässä tietojärjestelmätieteisiin sijoittuvassa väitöskirjassa keskitytään toiminnan jatkuvuuteen älykkäiden infrastruktuurien (eng. smart infrastructure) kontekstissa. Älykkäillä infrastruktuureilla tarkoitetaan tässä tutkimuksessa perinteisiä infrastruktuureja, kuten sähköverkkoja, vedenjakelua, ja tieverkostoa, jotka ovat digitalisoitu. Aihetta lähestytään erityisesti infrastruktuurin parissa toimivien teknikoiden työn kautta. Teknikoiden työ näissä ympäristöissä on nivoutunut kiinteästi yhteen tietojärjestelmien ja teknologioiden kanssa, jotka muodostavat infrastruktuurin. Älykkäät infrastruktuurit muodostavatkin näin erityisesti tietojärjestelmätieteiden tutkimukselle kiinnostavan, mutta vähän tutkitun kontekstin. Tutkimus pohjautuu teoreettisesti sosiomateriaalisuuteen ja nojaa erityisesti Karen Baradin filosofiseen ja teoreettiseen viitekehykseen toimijarealismista (eng. agential realism). Tutkimuksen tavoite on tuottaa ymmärrystä siitä, miten infrastruktuurien jatkuvuus toteutuu käytännössä. Tätä tavoitetta on tässä väitöskirjassa tutkittu kuuden vertaisarvioidun artikkelin kautta.

Menetelmällisesti tutkimuksessa on nojattu sekä konseptuaaliseen että empiiriseen tutkimukseen. Konseptuaalinen tutkimus keskittyy toiminnan jatkuvuuden ja

sosiomateriaalisuuden käsitteiden ja lähestymistapojen kehittämiseen sekä selventämiseen argumentoinnin ja kirjallisuuskatsauksen avulla. Empiirinen tutkimus pohjautuu laadulliseen tutkimusotteeseen ja nojaa etnografiseen tutkimusmenetelmään. Kuten etnografiselle tutkimusmenetelmälle on luonnollista, aineisto pohjautuu pääosin osallistuvaan havainnointiin yhdessä organisaatiossa, jota on tutkittu intensiivisesti. Heijastaen tutkimuksen tavoitetta ja ongelmanasettelua, etnografinen tutkimus suoritettiin älykkään infrastruktuurin (sähköverkon) keskitetyssä valvomossa, jossa teknikoiden työtä tietojärjestelmien ja teknologioiden parissa seurattiin useiden kuukausien ajan.

Tutkimuksen tulokset osallistuvat infrastruktuurien toiminnan jatkuvuuden ja sosiomaterialisuuden keskusteluihin. Tutkimuksen keskeisin tulos toiminnan jatkuvuuden tutkimukseen on toiminnan jatkuvuuden konseptualisointi suoritettuna toimintana. Tämän konseptualisoinnin mukaan toiminnan jatkuvuus ei ole jonkin menetelmän ominaisuus vaan jatkuvuus tuotetaan yhteisesti sosiomateriaalisessa toimijoiden verkossa toistuvien tekojen kautta. Tutkimuksen tulokset siis haastavat mutta myös edistävät aiempaa kirjallisuutta toiminnan jatkuvuudesta. Lisäksi, tutkimuksen tulokset edistävät keskusteluita toimijuuden sosiomateriaalisuudesta. Tulosten valossa, kun toimijuutta tarkastellaan infrastruktuurikontekstissa, on toimijuus historiallinen, polysentrinen, dynaaminen ja yllätyksellinen.

ACKNOWLEDGEMENTS

The pen is stubborn, sputters—hell! Am I condemned to scrawl? Boldly I dip it in the well. My writing flows, and all I try succeeds. Of course, the spatter Of this tormented night Is quite illegible. No matter: Who reads the stuff I write? (Nietzsche, 1974/1887, pp. 65-66)

Anyone who has done any creative work will likely find Nietzsche's frustration, angst, and hesitation familiar. At least on my own behalf, I feel more than deep sympathy. The moments of frustration when one is not able to put one's thinking into words are often followed by the moments of what Bertrand Russell (1945) calls as moments of *divine intoxication*, when all seems clear and the parts finally duly interrelate. However, this feeling is often misleading, and the moment merely brief and passing. These moments of "Eureka!" filled with joy and even slight euphoria provide the relief and reward for the creative mind but will soon fade away as doubt and uncertainty will again occupy the mind a moment later.

But what commonalities do creative work and science have? Isn't creativity a virtue of arts and rationality that of science? Mark Buchanan (2011) argues in the prestigious Nature that being rational is "not the same as being wise, and certainly not the same as being a good scientist. If the young student Einstein had been too rational, he'd have concluded he probably had very little chance of overturning the foundations of physics as established by the likes of Newton and Galileo." (p. 831) Clearly, my own research goals have been less grandiose and ambitious than overturning the foundations of physics, but I have found the creative aspect of scientific work most engaging and rewarding. And if there is one insight over others that I have learned during this journey, it is the creativity required in any good scientific work.

Creativity benefits from a right kind of milieu and from encounters (and confrontations) with open-minded people. Indeed, through this research process I have come to appreciate the importance of a dialogue. Not as a way of collecting answers from others or as a way to externalize the thorny tasks of problem-solving and thinking, but as a way of thinking. "I do not speak *of* my thoughts; I *speak* them and what is between them" (emphasis his) (Merleau-Ponty, 1964, p. 18). As Heinrich von Kleist (1951/ca. 1878) advises, "I[f] there is something you want to know and cannot discover by meditation, then, my dear, ingenious friend, I advise you to discuss it with the first acquaintance whom you happen to meet. He need not have a sharp intellect, nor do I mean that you should question him on the subject. No! Rather you yourself should begin by telling it all to him" (in Hamburger, 1951, p. 52). I certainly wish not to judge the intellect of any with whom my paths have crossed during this journey but to express my gratitude to everyone with whom I have had the chance to engage in dialogue and who are too numerous to list here. However, I do wish to use this opportunity to point out certain institutions and individuals who have had a particularly significant part in this research.

I'm greatly in debt to the Turku Centre of Computer Sciences (TUCS) and the University of Turku Graduate School (UTUGS) for the doctoral candidate positions they have offered me. The financial support these graduate schools have offered has enabled me to pursue this dream of becoming a doctor. The academic freedom to pursue new ideas and areas without immediate concerns over profit or practical applicability would not have been possible without these institutes. I have sought, to best of my abilities, to translate this opportunity and freedom into an academic contribution as documented within the covers of this tome. In addition, I would like to thank the Turku University Foundation and the Turun Kauppaseuran Säätiö for the generous travel grants they have offered, which have complemented my travel budget.

Further, this dissertation would not have been possible without the help of Turku Energia Sähköverkot. Especially, all the opportunities and support that Harri Salmela offered allowed me to closely study the work they do. Without his support, the research would have materialized quite differently. In addition to him, I owe thanks to all those working in and around the operations center who were kind and open-minded enough to welcome me (uninvited) into their lives and for having the patience to explain and show me their daily work.

I'm most grateful to professor Francois-Xavier de Vaujany and professor Petter Almklov for the honor of agreeing to review this dissertation. I have utmost respect and sincere admiration for their expertise in the areas this dissertation intersects with. Thus, I could not have hoped for a higher standard for the reviews of my manuscript. In addition, I'd like to thank professor Francois-Xavier de Vaujany for agreeing to be my esteemed opponent.

In addition, I'd like to express my gratitude to Dan Harnesk and John Lindström. While their influence on this dissertation has been less direct, their broader influence has been large. Without them I might not be writing these acknowledgements. As a master's student, I was inspired by Dan's way of engaging us students into debates and to question his arguments. His ability to view things from a new perspective and from an alternative angle I had not thought of before inspired me. His influence greatly affected my choice to continue for a PhD. While John's energy and efficiency are certainly merits, his openness and willingness to take me on, as a master's student, as part of his research project were even more admirable. This project led to my first publication and was indispensable help in paving the way for my doctoral position and to obtain a TUCS-financed position. Looking back at the publication now, I can certainly say it has some rough edges, but despite its shortcomings, most importantly, it showed and educated me on what it is to do scientific work.

Throughout this process my supervisor, Jonna Järveläinen, has been most supportive and maintained her always positive, and cheerful attitude—even during those moments when I have not been even sure myself whether I understand what it is I seek to explain. Especially, her ever-encouraging, creative, and supportive comments have helped to move past difficult points during this journey. In addition, I would like to thank my other supervisor, professor Hannu Salmela. While our interaction has not been as active as that with Jonna, I have constantly known that I can count on Hannu's expert advice and help when needed. Further, I'd like to thank the head of our department, professor Jukka Heikkilä, for being able to be a part of this inspiring group of scholars that constitutes the information systems sciences department.

Of my peers, I'd like to thank Gijs van den Heuvel who has had profound influence on my understanding of the peculiarities, strangeness, and ambiguities of sociomateriality and, in particular, agential realism. The expertise and all the deep thinking he has brought to numerous discussions and debates we've had over the years have been invaluable to my learning. In addition, I would like to thank the scholars at the University of Paris-Dauphine, who welcomed me for a research visit and with whom I got the chance to discuss and exchange ideas during my stay.

Without all my colleagues at the University of Turku, this journey would've not been as fun, lively, joyful, and engaging. Especially, I would like to thank Olli Sjöblom for all the recreational coffee breaks and entertaining discussions; Ab for his friendship and for being a great and exemplary scholar who's always willing and eager to explore any topic imaginable and who has so often helped to untie some of the tight knots in my own thinking; Neeraj for being a good friend and support who's always ready to offer his help; Hongxiu for all the encouraging complements and the trust she has shown in my work; Ping for being so energetic and bringing brightness even to the darkest of the winter days; Najmul for being an inspiration to high-quality publishing; Tingting for sharing her enthusiasm and passion for qualitative research; Jose for sharing his insights into and expertise on the complexities and politics of academia; Anne-Marie for all the discussions on research, politics, and various other topics; and last but not least Markus Zimmer for all his hard work and effort, which have been so crucial in unburdening me of my other work tasks such that I've been able to focus on writing this dissertation.

I want to also thank my family and friends for being there for me and providing balance to my academic work, and who I feel I have so often neglected due to approaching deadlines, workload, and travel. Special thanks goes to my mother Eija and my father Pentti, who have always been so supportive, caring, and encouraging; to my sister Marika and her family and to my brother Mika for their support; to my parents-in-law Katriina and Markku Laaksonen for their warm support and for the genuine interest and curiosity they have shown toward my work; and to my brother-in-law, Jaakko Laaksonen, for being a cheerful companion. And my thanks to my close friends Jaakko Myllärinen and Leila Niittymäki, who have provided me invaluable breaks from academic work but also hard competition and encouragement in endurance sports. Their support has helped me to push myself over the finish line of a marathon but also the finish line of this journey.

And last, I want to express my deepest gratitude to my dear friend, and wife, Elina, who has listened and supported me throughout the process; in each corner, on each downhill, and on each uphill. Her broad knowledge and large heart still amaze and surprise me each and every day.

Despite all the help that I have received during this process, I take the sole responsibility for the contents between the cover pages. I hope this dissertation manages to confront and challenge at least some of the readers' views and shake some of their taken-for-granted assumptions. After all:

> We read to be moved. A text that simply reinforces what we already know, no matter how well written, bores us. Reading is the search for engagement, a give and take, the start of a dialogue that will change the way we think, alter our feelings, transform our outlook. (Kipnis, 2015, p. 48)

23 May 2017
Marko Niemimaa

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1 INTRODUCTION

Each individual misfortune, to be sure, seems an exceptional occurrence; but misfortune in general is the rule. (Schopenhauer 1970/1850, p. 3)

1.1 Background and motivation

“Thousands left without electricity in Southwestern Finland” (Turun Sanomat, 2015), “Wind already dangerously strong” (Yle, 2015b), “Storm cut a power wire and ignited a surface fire” (Yle, 2015a), “Storm tears off a roof, cuts trees, and electricity” (Yle, 2015c). These are the kinds of headlines that started to appear on April 8, 2015, in Finnish national newspapers as a storm was sweeping across the country. As the storm took place on the day that is Suoma’s name day, the storm was named after her as is customary. The wind blew hardest in the western and southwestern parts of the country but had some impact on most other parts as well. Suoma was not an exceptional occasion, and not even exceptionally strong storm, blowing only approximately 25m/s. Nevertheless, it impacted the daily flow of society as fallen trees blocked roads, damaged houses and other buildings, and cut electricity from thousands of people. In these moments, the infrastructures that often go unnoticed become very visible (Star & Ruhleder, 1996) and transform into concrete barriers to people’s activities.

Nearly everything we do in contemporary organizations and societies depends on infrastructures. Making our morning coffee, commuting to the workplace, communicating with our friends and colleagues, lighting and heating our homes and workplaces, arranging meetings online and offline, writing and publishing our creative work, to name a few, all depend on infrastructures, and all become impossible (or at least severely impaired) when infrastructures fail. Infrastructures are surely the lifeblood of any modern society, and they are also its linchpin.

As the broader society experiences the impact of the storm through the failures in infrastructures that hinder – or even prevent – their work and everyday life, behind the scenes technicians are busy performing their work. These moments of breakdown are moments when the technicians become the epicenter of societies that are eagerly awaiting and demanding answers to the pressing concern—“when will it be repaired?” The technicians’ daily maintenance tasks that seek to ensure *a priori* that such breakdowns will not take place become abruptly and forcefully disrupted and give way for work to repair the infrastructure.

At the time when Suoma was causing destruction and havoc, at a power distribution company's operations center in the Southwestern corner of Finland, technicians were busy finding ways to restore the flows of electricity to their subscribers. All available and capable field technicians were sent to the field, and all desks were manned at the operations center. Storms are especially challenging for power grid operators, as the flows of electricity become disrupted immediately as falling trees or flying tree branches come in contact with the exposed electrical wires connected to utility poles. Situated in front of rows of displays, keyboards, mice, phones, office appurtenances, and large screens, the technicians at the operations center sought ways to coordinate the field technicians as more alerts poured in to notify the technicians of new outages but also of automatic repair actions the power grid technologies had performed. By utilizing the remote diagnostics, the technicians were able to see the flows of electricity and the topological configuration of the grid in real-time. By using remote control, they could isolate and circumvent the faulty parts, but only as long as the topological configuration afforded. And when it did not, all they could do was to wait for the field technicians to reach the physical location. The storm seemed persistent and did not seem to let the technicians of the hook too easily this time. As faulty parts were repaired, new faults appeared in old and new places. Finally, as the day turned to night, the storm finally showed signs of weakening. Before night fall, almost all faults had been repaired. It was finally time for the day shift to go home after a long and exhaustive day at work and hand the rest over to the night shift.

Other similar and more severe cases where infrastructures have failed abound in the literature and in news reports, like the massive Northeast American blackout in August 2003 that affected around 50 million people (Bennett, 2005); the blackout that took place in March 2015 in Turkey and hit 49 of the country's total of 81 provinces, including the capital Ankara and Istanbul (The Guardian, 2015); and the blackout in Amsterdam in January 2017 that left almost 400 000 people without electricity and put a halt to train and tram traffic (Euronews, 2017). According to Bruch et al. (2011), power failures in the US alone "sum up to an annual economic loss between USD104bn to USD164bn" (p. 16). Similar figures are reported by the US Department of Energy (2008), which has calculated that power outages and disruptions "cost Americans at least $150 billion each year—about $500 for every man, woman and child" (p. 5). While it is hard to estimate the costs *all* infrastructure failures add up to, suffice it to say that the figures are likely to be many-fold. Against these enormous figures and catastrophic events, Suoma seems prosaic and insignificant. However, the Suoma case illustrates well the significance of these infrastructures and their business continuity (hereafter: "infrastructure continuity"). But the case also reveals some insights into the internal dynamics of the ways in which the technicians perform their work to repair the infrastructure through which its continuity becomes (re)established; how they perform is certainly not a small matter!

Especially in Western societies, our experiences with infrastructures often paint an image of stability, rigidity, and permanence. This image seems to be largely misleading and deceiving. Infrastructures, as large-scale technological systems, as Perrow (1981) argues, have a propensity for “normal” accidents. Closer analysis of infrastructures seems to suggest, ipso facto, that in contrast to everyday experiences, infrastructure “is always a precarious achievement ready to untangle at a moment’s notice through myriad of possible causes” (Graham, 2010, p. 11). While it is the large-scale failures and catastrophes that have become the epitome of infrastructural breakdowns, as depicted by the media and many studies (e.g., Bennett, 2005; Reason, 1997; Weick, 1993), it is all the prosaic breakdowns that are not just incidental moments of failure but also an essential and intrinsic part of the ebb and flow of infrastructures. Infrastructure continuity is thus not a straightforward matter, as, in their functioning, the infrastructures become established through complex and uncertain processes that involve a number of factors and actors (c.f., Bennett, 2005). Organizations face a challenge to perform reliably with inherently unreliable technologies (Butler & Gray, 2006). Consequently, understanding those complex and uncertain processes is a key concern for organizations that are responsible for infrastructures.

The operation of modern power grids, water distribution systems, road networks, railroads, oil drilling platforms, and so forth is largely dependent on information systems (ISs) (Alcaraz & Zeadally, 2015) which makes these smart infrastructures an interesting yet rather unexplored topic for IS research (Constantinides, Henfridsson, & Parker, 2016). While the design and development of infrastructures have received some attention for decades (e.g., Star & Ruhleder, 1996; Hanseth & Monteiro, 1997), scholars have merely started to explore them as a context for IS use and work. Among these contributions, IS scholars have studied such aspects as changes to nomadic work (Cousins & Robey, 2005; Mark & Su, 2010), to perceived proximity in distributed work (Wilson, O’Leary, Metiu, & Jett, 2009), and to technical support work (Pollock, Williams, D’Adderio, & Grimm, 2009). But in addition to these changes, technicians’ work has been profoundly influenced by the digital transformation of traditional infrastructures into smart infrastructures.

Technicians’ work has been of sustained interest for IS and management and organization scholars (e.g., Barley, 1996; Orr 1996; 2006; Zuboff, 1988), yet “new frontiers” of work have emerged at the intersection of the information, technology, and work (Forman, King, & Lyytinen, 2014) that are “enabling new capabilities and activities in ways that would have been unimaginable even a decade ago”

(Constantinides et al., 2016, p. 1). Broadly, the digitalization of these infrastructures has led to an unprecedented centralization of maintenance services that used to be locally organized (Jonsson, Holmström, & Lyytinen, 2009). Even repair and diagnostic tasks that used to be highly localized (e.g., Orr, 1996) have become centralized (Pollock et al., 2009). Indeed, maintaining clear separation between local and non-local aspects of technicians' work has become increasingly challenging and blurry in these contemporary infrastructure settings (Wilson et al., 2008; Almklov, Østerlie, & Haavik, 2014). Central to these changes is that performing the work "rests on the materiality of the technology" (Jonsson et al. 2009, p. 250) in such a way that "sensory information becomes their [technicians'] work material" (Jonsson et al. 2009, p. 249). These technologies do not merely mediate some existing information and reality but also create information and enact new realities in which the technicians perform their work (Almkov et al., 2014; Østerlie, Almklov, & Hepsø, 2012; Jonsson et al., 2009). The technicians' contemporary "tools" (e.g., the information systems and the technological arrangements that jointly create the sensory materials) can no longer be described in terms of extensions of our corporeality or as mere background for action but rather as constitutive and active parts of the work.

As the technicians and technologies have become constitutively entangled, it has also become impossible to discern the performance of work in its constitutive parts in any meaningful way. Rather, it encourages us to consider the possibilities they jointly produce and how these possibilities shape the resulting performances. This also means that "capacities for action are seen to be enacted in practice and the focus is on constitutive entanglements (e.g., configurations, networks, associations, mangles, assemblages, etc.) of humans and technologies" (Orlikowski, 2010, p. 135). As such, for the technicians, the infrastructure is simultaneously a topic of concern and a context for action. The reason why any of this is of significance is because what work the technicians do and how they perform their work contributes significantly to infrastructure continuity (c.f., Butler & Gray, 2006; Graham & Thrift, 2007).

In the prior literature, concerns over managerial frameworks for planning and managing the business continuity of organizational functions have largely overshadowed the considerations of the actual performance of work (Herbane, 2010). The managerial frameworks, such as international standards (e.g., the International Organization for Standardization's (ISO) ISO/IEC-27001 Information security management systems (2013), or ISO-22301 Business continuity management systems (2012)), are often referred to as "best practices" (Siponen & Willison, 2009). They provide acontextual abstractions of practices that organizations should adopt and embed in organizational practices and routines (Hebane, Elliott, & Swartz, 2004; Gibb & Buchanan, 2006; Niemimaa & Järveläinen, 2013). These frameworks are "largely *prescriptive,* in that they describe *what* should be done to protect IT assets, but not *how* a particular activity should be performed" (emphasis his) (Hiles, 2011, p. 737). While these approaches are likely beneficial for improving organizational measures, they tell less about the ways in which those organizations actually perform in establishing the continuity of their organizational functions.

Organizations rarely perform as they document or as the management thinks about or describes the organizational work (Orr, 2006). That is, there is likely to be a difference between the organizational canonical (documented) practices and non-canonical (enacted) practices (Niemimaa & Niemimaa, 2017; Feldman, 2000). Consequently, it is unlikely that organizations' infrastructure continuity performance could be inferred from organizational documents or from management structures and processes but has to be studied *in situ*. Otherwise, we are at risk of continuing to treat the infrastructure continuity as a "black box" that is analyzed only from a distance without knowing much about its internal dynamics (c.f., Nicolini, 2009). Without knowing these internal dynamics, we are likely to fail to enact meaningful improvements that contribute to those processes through which infrastructure continuity becomes achieved.

To contribute to understanding infrastructure continuity, this dissertation research focuses on the "black box" to uncover some of its internal dynamics. As prior literature has established, understanding the performance of work in smart infrastructure contexts requires accounting for the materiality of those environments. Following this recognition, and the prior literature studying similar contexts and work (Østerlie et al., 2012; Almklov et al., 2014; Parmiggiani & Monteiro, 2015; Mikalsen, Parmiggiani, & Hepsø, 2014), the research studies infrastructure continuity from a *sociomaterial* perspective that builds on *agential realist* foundations (Barad, 2003, 2007). "From this vantage point, *social* and *material* are each simply selective projections of a tangled whole" (emphasis theirs) (Mazmanian, Cohn, & Dourish, 2014, p. 832). These foundations have been found "particularly useful for studying this type of work (i.e., work that is constitutively entangled with IIs [information infrastructures] that stretch out of the local setting)" (Almklov et al. 2014, p. 265).

1.2 Purpose of the research and research questions

Building on the above discussion, the purpose of this research is to increase the understanding on *how continuity becomes performed in a smart infrastructure context.* In other words, the dissertation focuses on understanding how the phenomenon of infrastructure continuity unfolds in the smart infrastructure context rather than finding ways of how it should unfold. The infrastructure continuity is explored from a sociomaterial perspective that builds on agential realist foundations.

I will pursue this purpose by casting three guiding research questions:

- *How can organizational business continuity be understood?* (RQ1)
- *How can materiality be theorized in a smart infrastructure context?* (RQ2)
- *How does the performance of actions emerge in a smart infrastructure context?* (RQ3)

These questions are partly transitive and form a research process in which different phases feed back to and influence the overall scope and purpose of the research, as is typical for qualitative research (e.g., Maxwell, 2008). These questions contribute to the purpose of this study by focusing on three broader themes: (1) business continuity, (2) sociomateriality, and (3) smart infrastructures.

1.3 An overview of the research articles of the dissertation

The research questions outlined above are explored through six research articles. These six articles form the foundations for this synopsis. That is, the synopsis forms an independent piece that is founded on the six research articles but is an emergent outcome of the whole research process. Figure 1 provides an overview of the relationship between the research articles and the research questions (see Table 1 for the full titles of the articles). With the approval of the publishers, the original articles are appended to this dissertation as Appendix B: Selected publications.

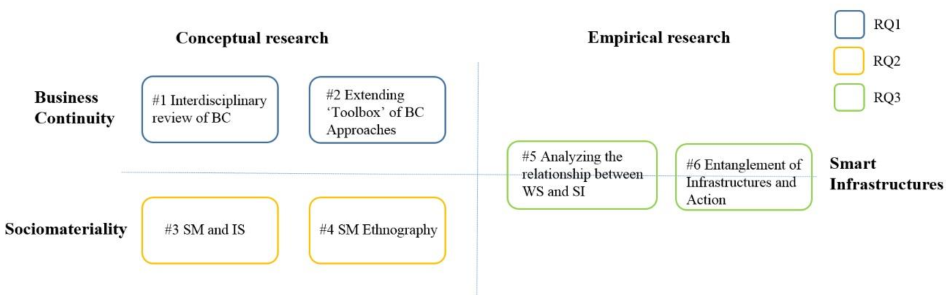

Figure 1. An overview of the research articles and research questions

Table 1 provides an overview of the articles and how each of the papers relates to the purpose of the study.

Table 1. An overview of the research articles and their relationship to the dissertation

Article	*Main theme(s)*	*Role in thesis*
#1 Interdisciplinary Review of Business Continuity from an Information Systems Perspective: Toward an Integrative Framework.	Business Continuity and Information Systems.	Provides reference literature and foundations for understanding business continuity.
#2 Extending 'Toolbox' of Business Continuity Approaches: Towards Practicing Continuity.	Business Continuity, Sociomateriality.	Provides conceptual discussion and elaboration of the relationship between business continuity and material boundaries of actions.
#3 Sociomateriality and Information Systems: Quantum Radicals and the Cartesian Conservatives.	Sociomateriality, Infrastructures.	Provides the theoretical and philosophical foundations for analyzing entanglement between humans and technologies (materiality), i.e., sociomateriality.
#4 Sociomaterial Ethnography: Taking the Matter Seriously.	Sociomateriality	Provides a discussion and methodological criteria for empirical sociomateriality research.
#5 Analyzing the Relationship Between Workspace and Smart Infrastructure Reliability and Continuity: An Ethnography of Technicians' Work	(Smart) Infrastructures, Business Continuity, Sociomateriality.	Provides an empirical account of the ways in which the (smart) infrastructure and the technicians' possibilities for performing continuity are entangled.
#6 Entanglement of Infrastructures and Action: Exploring the Material Foundations of Technicians' Work in Smart Infrastructure Context	(Smart) Infrastructures, Sociomateriality (agency).	Provides an empirical account and further theorizing on smart infrastructures as contexts for action.

All articles except article #5 are single-authored. I am the first author of article #5, and my part in the research was significant.

2 INFORMING LITERATURE AND THEORETICAL ELEMENTS

I want to value a style of connected thinking and writing that troubles the predictable academic isolation of consecrated authors by gathering and explicitly valorizing the collective webs one thinks with, rather than using the thinking of others as a mere "background" against which to foreground one's own. (de la Bellacasa, 2012, p. 202)

I have drawn on three different and previously rather isolated streams of literature to form the conceptual and theoretical foundations of the study (see Figure 2). All three of these streams have received broad multidisciplinary interest but are also areas that IS researchers have touched upon, albeit with varying levels of engagement. I have sought to weave webs, surface connections, and enact interactions between authors and ideas on "streams [of literature] not typically cited together" (Locke & Golden-Biddle, 1997, p. 103). As such, the reading follows ideas embedded in Barad's (2007, 2014) notion of diffractive reading—reading literature through each other and surfacing differences and similarities that matter. These streams partly emerged from an inductive, iterative, and cyclic research process during which new ideas surfaced and fed back to and influenced the overall research focus (see "3.3.1: Empirical material"). Next in this chapter, I will provide an overview of these three literature streams as follows. I will first provide a discussion on infrastructures and then one on business continuity, which is followed by a discussion on sociomateriality. Lastly, I will draw connections between these ideas to outline a performative view on infrastructure continuity.

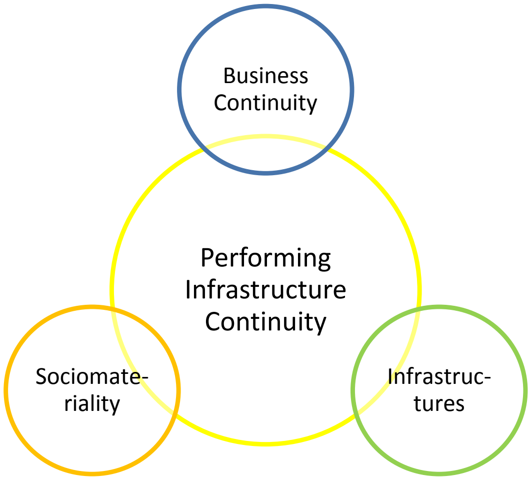

Figure 2. Conceptual and theoretical foundations of the dissertation

2.1 Infrastructures

Choices that appear to be merely technical will redefine our lives together at work. This means more than simply contemplating the implications or consequences of a new technology. It means that a powerful new technology, such as represented by the computer, fundamentally reorganizes the infrastructure of our material world. It eliminates former alternatives. It creates new possibilities. It necessitates fresh choices. (Zuboff, 1988, p. 5)

IS research has studied infrastructures for a long time (e.g., Hanseth & Monteiro, 1997; Star & Ruhleder, 1996) and has found them an intriguing but challenging topic. Special issues dedicated to the topic chart the agenda for infrastructure studies in IS (Edwards, Bowker, Jackson, & Williams, 2009), study innovations in infrastructures (Monteiro, Pollock, & Williams, 2014), and foreground intersections between infrastructures and platforms (Constantinides et al., 2016). A dedicated panel discussion has appeared in one of our most prestigious conferences to explore the practice perspective on infrastructure studies (Klein, Reimers, & Johnston, 2012). Calls have been made for the IS community to shift the focus from individual information systems to infrastructures (Tilson, Lyytinen, & Sørensen, 2010a,b; Monteiro et al., 2013).

Next, I will elaborate what an infrastructure actually is, or, more accurately—when an infrastructure is (Star & Ruhleder, 1996). After introducing the characteristics of infrastructures, I will provide a discussion on some of the key areas in infrastructure studies.

2.1.1 Characteristics of an infrastructure

Defining what an infrastructure is, is a difficult and thorny quest, as already noted by Star and Ruhleder (1996) in their seminal article on the topic. Outside of academic vernacular, the concept is often used rather self-evidently. It refers to some sort of constellation of united (but not unified) and distributed yet tightly interconnected "things" that provide us the most fundamental services, such as water, electricity, communications, and transportation. Or, as Star and Ruhleder (1996) argue, "[c]ommon metaphors present infrastructure as a substrate: something upon which something else 'runs' or 'operates'… It is something that is just there, ready-to-hand, completely transparent" (p. 112). As they note, such use has several ambiguities, such as "for the plumber, the waterworks system in a household connected to the city water system is target object, not background support" (p. 113). Yet, infrastructure still remains as an infrastructure. In considering the ambiguities, Star and Ruhleder (1996, p. 113) determine that an accurate question is not *what* an infrastructure is but rather *when* an infrastructure is. They define eight infrastructural characteristics:

- *Embeddedness*: Infrastructures are always embedded in other infrastructures.
- *Transparency*: Infrastructures are transparent to use (i.e., invisible to users).
- *Reach or scope*: Infrastructures extend over spatial and temporal scales.
- *Learned as part of membership*: Infrastructures are always encountered by new participants as target objects to learn about.
- *Links with conventions of practice*: "Infrastructure both shapes and is shaped by the conventions of a community of practice" (p. 113).
- *Embodiment of standards*: Infrastructures connect to other infrastructures in standardized ways.
- *Built on an installed base*: "Infrastructure does not grow *de novo*: it wrestles with the 'inertia of the installed base' and inherits strengths and limitations from that base" (p. 113).
- *Becomes visible upon breakdowns*: Infrastructures surface as visible only when they break down.

I have found these eight characteristics a useful way to think about infrastructures. I would add that infrastructures are also (9) C*onstitutively dynamic* and (10)

Difficult to demarcate. What I mean by constitutively dynamic is that the installed base of infrastructure varies from moment to moment. Some of these changes are controlled, whereas other are abrupt and disruptive. The controlled changes are what Hanseth and Lyytinen (2010) consider to be the *openness* of infrastructures—that they are open for users to become part of the infrastructure; for example, a user may connect to the Internet by buying a subscription. New participants may also become members abruptly such as when, for instance, a hacker infiltrates an organization's communications infrastructure or a culprit connects illegal wire to a utility pole to steal electricity.

What I mean by difficult to demarcate is that the boundaries of infrastructures are never quite visible and can be defined in multiple ways. The Internet is an infrastructure, but it is also a collection of infrastructures when demarcated by the administrative borders that often, but not always, reflect the autonomous systems (ASs). Modern power grids embody mechanical switches and other non-information technologies (ITs) that used to form the material foundations. But nowadays the grids are operated through information systems and other technological components such as relays and remotely controllable switches that operate on an embedded Linux (or on some similar operating systems). As such, while infrastructures are embedded into infrastructures, drawing boundaries is often arduous, arbitrary, and might often be political, economic, and contested. Demarcating infrastructures in the case of, for instance, failure is often economically driven, as outages can incur costs or other liabilities to those who are found responsible. But such demarcations may also surface political conflicts within an organization. For instance, determining whether an organization's power grid management information system is part of the IT infrastructure or power grid infrastructure may become contested, as it also often determines structures of responsibilities (e.g., whether it is the IT department or power grid technicians' responsibility).

While these characteristics pertain to infrastructures in general, smart infrastructures are a specific type of infrastructure (Constantinides et al., 2016). In a white-paper that resulted from an industry and academy cooperation, Bowers et al. (2016) define it as follows: "[s]mart infrastructure is the result of combining physical infrastructure with digital infrastructure, providing improved information to enable better decision making, faster and cheaper" (p. 2). Their definition matches well with the ideas embedded in Zuboff's (1988) "smart machines" (i.e., modern computers) in that they not only *automate* work but that they also *informate*—that is, they produce *new* information. In contrast to information and digital infrastructures (e.g., the Internet and cloud platforms) (Tilson et al., 2010a,b; Hanseth & Lyytinen, 2010), smart infrastructures are always anchored to the messy, rigid, and persisting "real" materials of the world and are also used to manipulate those materials. In other words, they are "layered" infrastructures such that they combine aspects from both digital and physical infrastructures. However, as digital technologies are increasingly becoming inseparable and inherent part of all aspects of infrastructures, separating these two layers is becoming increasingly challenging and they remain merely as analytical categories. Already now, we are seeing digital technologies being deployed in the most traditional power infrastructure components, such as in switches, sensors, and relays. While it can be argued that information and digital infrastructures are also tied to servers and other hardware, these infrastructures, however, operate in the domain of the "virtual," which is a different simulacrum of reality with its own limitations and rules. Smart infrastructures differ from traditional power grids, water distribution systems, and so forth to the extent that they are digitalized. That is, smart infrastructures always embody technologies that enable remote monitoring and control as well as some degree of autonomous and automatic functioning. This digitalization marks the difference between "smart" and "traditional" infrastructures. When viewed from this perspective, critical infrastructures can also be smart infrastructures if their operations rely on (digital) technologies and on automation; they differ only in relation to their criticality.

2.1.2 Design and evolution of infrastructures

Research on infrastructures in IS research has established that infrastructures pose quite a different object of design than traditional information systems. The wide user-base, generativity, and openness of these infrastructures make it difficult, or even impossible, and, at least insensible, to dictate strict *a priori* boundaries on their use. When one thinks about what the Internet is today, it is quite obvious that no one actually *designed* it but that it evolved (Hanseth & Lyytinen, 2010). Ciborra and Hanseth (2000) call this evolving tendency *drifting*. Infrastructures seem to drift away from and avert management control. As they drift, they "deviate from their planned purpose for variety of reasons often outside anyone's influence" (p. 4). More recently, Constantinides and Barrett (2014) studied the governance of the infrastructure development of a new health infrastructure and showed how the infrastructure evolved from the bottom up through a series of collective actions involving struggles over meaning, shifting power relations, and legitimacy issues. However, how infrastructures evolve is not a free-flowing activity but rather always conditioned by the past. Several scholars have shown that despite this evolutionary development, infrastructures' development seems to exhibit path dependency (e.g., Star & Ruhleder, 1996; Hanseth & Lyytinen, 2010; Venters, Oborn, & Barrett, 2014). The evolutionary development is not merely tied to digital/information infrastructures but seems to affect more traditional types of infrastructures as well. "The prime example of a dynamical self-organizing system may be the Internet, but most communication infrastructures, road and transportation systems, supply networks, and power distribution grids are also dynamically growing networks" (Vespignani, 2009, p. 427). Indeed, one could argue if there's one infrastructure that has evolved even more dramatically and that has had even more generativity than the Internet, it is the power distribution system. The infrastructure that was once developed to power lightbulbs in factories (Hughes, 1993) now powers all aspects of our lives—including the Internet. But infrastructures are not merely an interesting topic due to their design challenges (Hanseth & Lyytinen, 2010); they also form a different context for work.

2.1.3 Infrastructures as a (material) context of work

Hanseth and Monteiro (1997) studied the role of standards in an infrastructure context. By studying a health infrastructure development process, they found that standards become embedded as inscriptions in the infrastructures and that they subsequently prescribe behavior when acting with those infrastructures. As such, their findings suggest that infrastructures seem to constrain actions and that this constraint seems to emerge from their history (i.e., how the infrastructure has developed). Venters et al. (2014) studied the development *and* use of a very special kind of infrastructure—the CERN grid. What they found was that both the development and use of the infrastructure are constrained by history. They also argued that while the development and use are activities that are historical, they are oriented toward the future but happen in the present (i.e., "trichordal agency"). Thus, "projected futures and inertias of the past are also enacted within the ongoing development and use of digital infrastructure" (Venters et al., 2014, p. 946). Interestingly, their study also brings closer the development and use as perhaps two sides of the same coin—infrastructure may also become developed (read: evolve) through use. But in these studies, infrastructure is no longer solely the object of development but also a context of use and action.

When studying infrastructure as a context, it does not mean that the infrastructure is "simply a 'substrate' upon which something 'runs'. Rather, it establishes and sustains particular types of relations and actions, while disabling others" (Ribes et al., 2013 in Venters et al., 2014, p. 945). By establishing and sustaining these particular types of relations and actions, the infrastructures have profoundly reconfigured the work that technicians do and have enacted new realities in which to work. This is especially, true for smart infrastructures.

Østerlie et al. (2012) provide a detailed study of technicians' practices of knowing in oil drilling context. The smart infrastructure that enables the technicians to know about the flows of oil combine sensors and information systems, which form what they call "dual materiality" arrangements. These dual materiality arrangements are responsible for creating materials for the technicians to work with that would not exist in the absence of these arrangements. As such, they argue that the technicians' knowing rests on the dual materiality arrangements that do not merely mediate some existing information but jointly enacts particular realities. Parmiggiani and Monteiro (2015) also studied oil and gas operations and how "facts" about the sub-sea environment become established. They argued that the established facts are not neutral but rather relational to the technologies through which these facts become created. But in addition, the smart infrastructures have significantly shaped the locality of technicians' work.

Studies have found that infrastructures enable performing work from a distance, which was thought earlier to be highly local. For instance, diagnostics work (Orr, 1996) can nowadays be performed remotely (Pollock et al., 2009). Jonsson et al. (2009) argued that remote diagnostics, through their materiality, enable new forms of boundary-spanning. Based on their findings, they argue that "the remote diagnostics systems do not merely transmit and store information; they also have the ability to produce and transform information that can be acquired by no other means…Maintenance work is now an increasingly complex socio-technical activity that fundamentally rests on the materiality of the technology" (p. 249). Indeed, "the tightly drawn infrastructural networks that characterize many contemporary societies routinely blur the distinction between things and human actors, producing hybrid" (Graham & Thrift, 2007, p. 4).

The distributed yet interconnected nature of infrastructures seems to be responsible some of the changes to the work. Almklov et al. (2014) studied computer-mediated technicians' work in the petroleum industry. What they argue is that infrastructures rework the *situatedness* of work. That is, by entangling technicians and (remote) sensors, the local/non-local boundaries become blurred and porous. In other words, these and other studies (e.g., Mikalsen et al., 2014) have shown that the smart infrastructures form a different kind of context for work and action. The work in these environment rests on the materiality of the technologies and the information they create but also that the materiality of these technologies enacts new realities that transform possibilities and conceptions of local/non-local work.

2.1.4 Continuity of infrastructures

As we have seen and experienced ourselves, infrastructures do fail. When they fail, the effects are often felt even at the societal level. Huge amounts of effort, money, and time are invested to maintain their functioning (Graham & Thrift, 2007). Perrow (1981) has famously argued that large-scale, complex systems such as infrastructures have a tendency toward failures. That is, infrastructure "is always a precarious achievement ready to untangle at a moment's notice through a myriad of possible causes" (Graham, 2010, p. 11). Star and Ruhleder (1996) have viewed this tendency as one of the eight characteristics of *when* an infrastructure is infrastructure. As such, in any infrastructure setting, there is a need for a "continuous flow of tasks and interventions undertaken to keep a system up and running" (Almklov & Antonsen, 2014).

During moments of breakdown, the infrastructure becomes very visible. Think, for instance, of the power grid needed for making morning coffee. When the power grid fails to provide electricity at these moments, the invisible power grid becomes very visible and a concrete barrier to our coffee making. Pipek and Wulf (2009) have shown how these moments of breakdown give rise to new patterns of work as other issues become less salient, and the active breakdown becomes the focus of attention—how should we fix it? "This moment [of breakdown] catalyzes 'in-situ design work,' both informal and formal, by both designated designers and users, that reconfigures and/or extends the existing work infrastructure to repair the breakdown" (Edwards et al., 2009). Bennett's (2005) extensive social analysis of a major smart infrastructure breakdown in the US surfaces new conceptions of distributed forms of agency but also shows how complex disentangling the web of forces and actors affecting the situation is. She argues that the "blackout [of a power grid] was the end point of a cascade—of voltage collapses, self-protective withdrawals from the grid, and human decisions and omissions" (p. 448). Against her analysis, condemning individuals ("human error") or blaming the technologies seem insensible to account for the complex dynamics through which the blackout unfolded. Further, studies categorized under the broad umbrella of High Reliability Organizations have studied organizational arrangements that engender reliable infrastructural performance in most demanding environments, such as in nuclear power plants and in flight control. These studies have established a strong connection between organizational arrangements, external factors, and technological configuration for reliable performance outcomes (e.g., La Porte, 1996; Schulman, Roe, van Eeten & de Bruijne, 2004).

Despite the recognized practical and academic significance, and the overall popularity of infrastructures in IS research, the topic of continuity has received surprisingly little attention from IS scholars. Even Tilson et al. (2009) provide an agenda for infrastructure studies in IS but almost fully bypass the topic. While they are clearly more interested in infrastructure development and design issues, bypassing the topic of continuity may neglect important development and design dynamics emerging from breakdowns, as discussed above. Fortunately, however, Edwards et al. (2009) account for these dynamics in their agenda. Outside of IS, especially in the engineering- and safety-related disciplines, the topic has gained significant attention and is recognized as one of the key requirements and challenges for 21st century critical smart infrastructures (Alcaraz & Zeadally, 2015). These approaches, however, often center upon modeling, simulations, and quantitative analysis that focus on a distal analysis of the phenomenon (e.g., Murray &

Grubesic, 2007), which omits the particularities and minute details that are necessary to understand such dynamics, as surfaced by Star and Ruhleder (1996), Pipek and Wulf (2009), and Bennett (2005).

Given the fact that "[t]he vast majority of, if not all, critical [smart] infrastructures are dependent on information systems" (Alcaraz & Zeadally, 2016, p. 54), they make a particularly interesting, intriguing, and yet largely unexplored area for IS inquiries (Constantinides et al., 2016). But how to move forward? How should this largely unchartered territory be approached? Scholars—within and outside of IS—have studied broadly the organizational preparations and measures for incidents under the rubric of business continuity. Business continuity seems especially appealing, since smart infrastructures are often among the most critical functions for the organizations that are responsible for those infrastructures.

2.2 Business continuity

Dealing with incidents and organizational breakdowns is a complex and diverse topic that has drawn multidisciplinary scholarly attention. Particularly scholars sharing an interest in business continuity have studied organizational preparations and measures for dealing with incidents. These efforts have focused broadly on addressing all types of contingencies, including supply chain failures (Zsidisin et al., 2005; Hinde, 2005; Norrman & Jansson, 2004), pandemics (Conseil et al., 2008; Ekmekci & Bergstrand, 2010), and even terrorist attacks (Alonso & Boucher, 2001; Paton, 2009), to name a few. While the topic has been of quite marginal and peripheral interest for the general IS community, a rather loosely coupled and multidisciplinary community has shared an interest in the role that IS has for business continuity. Nevertheless, the significance of the topic is well recognized among IS (security) scholars and practitioners (Siponen & Willison, 2007; Kappelman, McLean, Johnson, & Torres, 2016) and is considered one of the core areas of competencies for IS graduates (e.g., Topi et al., 2016).

2.2.1 Planning and management approaches to business continuity

A central theme in the previous literature has been managerial frameworks—collections of "best" practices and processes—that advocate planning or management as key for improving organizational business continuity (e.g., Botha & von Solms, 2004; Gibb & Buchanan, 2006). In planning approaches, business continuity plans are the primary outcome and form the foundations for business continuity. The planning approaches are commonly structured around similar phases (though the naming conventions may differ)[1] as follows:

- Project initiation
- Risk assessment/business impact analysis
- Design and development of plans
- Creation of plans
- Testing and exercising
- Maintenance and updating (Pitt & Goyal, 2004, p. 88)

The plans document organizational measures that provide a basis for recovery efforts in the unfortunate event of an incident. Once the plans have been created, they are left aside until a periodic review is performed. Such reactive orientation focuses on the anticipation of failures rather than actively seeking to maintain business continuity (Butler & Gray, 2006).

These planning approaches have been criticized for focusing too much on the plans and on the frameworks, as "[n]o matter what contingency planning process is used, the ultimate success of a contingency recover depends on the personnel implementing those plans and procedures" (Harris & Grimalia, 2008, p. 1). Suchman (2007) has convincingly shown that documented plans do not provide templates for action but function as an informational source when performing action. According to her, the plans can never match the contingencies and idiographic aspects of an unfolding situation and, thus, their application always requires making sense of the local or situated circumstances. The management approaches, on the other hand, underscore organizational change. A key to improvement lies not in the plans *per se* (though plans can be a part of the efforts). Instead, management approaches take the view that improvements follow from making changes to organizational work practices, and routines, but also from achieving employee commitment (also known as embeddedness) (Herbane et al., 2004; Niemimaa & Järveläinen, 2013). Thus, for management approaches, *improvements* are the results of the top-down implementation of the frameworks, but business continuity itself is an emergent of the actual (work) practices.

Herbane (2010) views planning and management approaches as different development phases on the same continuum of incident preparations. For both the planning and management frameworks, the focus is on finding the optimal set and procedural order of practices and processes that organizations should follow rigorously when implementing. These frameworks have given rise to a number of related concerns, such as why organizations do not adopt them (Alonaizan, 2009), how they should be implemented (McLoughlin, 2009), who should participate (Kendall et al., 2005) and lead the implementation (Seow, 2009; Lindström &

[1] Also, Stucke, Straub, and Sainsbury (2010) note that "[t]he set of activities that precede and surround a disaster are fairly well documented and do not differ substantially from one another across commentators" (Stucke et al. 2010, p. 163).

Hägerfors, 2009), how to prepare for their audits (Zambon, Bolzoni, Etalle, & Salvato, 2007; Freestone & Lee, 2008), how organizational risk management may benefit from them (Torabi, Giahi, & Sahebjamnia, 2016), how to facilitate technologies to support their implementation (Sapateiro, Baloian, Antunes, & Zurita, 2011; Sheth, McHugh, & Jones, 2008; van de Walle & Rotkowski, 2006), and how they influence financial and non-financial performance (Bakar, Yaacob, & Udin, 2015). The influence of these frameworks has been so pervading that often the frameworks and business continuity have become interchangeable. Besides the normative definitions the frameworks often advocate, they tell little about business continuity itself.

2.2.2 The social and technological approaches to business continuity

In addition to the planning and management frameworks, two other main approaches to business continuity focus upon technologies and social processes. When business continuity is approached as a technological topic and concern, technologies become the crux and are almost deterministic of organizational business continuity. For organizations, investing in new technologies is thus imperative to enable what Bajgoric (2006) refers to as "always-on-computing" that enables business continuity. Other similar examples include developing remote work technologies (Roitz & Jackson, 2006), creating mobile apps for communications (Sapateiro et al., 2011), enhancing preparedness for power outages (Asgary & Mousavi-Jahromi, 2011), and so forth. Indeed, industry (e.g., Business Continuity Institute, 2015; Ponemon Institute LLC, 2015) and academic (Kappelman et al., 2015) surveys seem to indicate year after year that failures in technologies are a major concern for IS managers. As such, new technologies feel like an appropriate panacea for the IS managers' nightmares. However, things may not be simply solved by merely investing in more of what is the actual source of the problem.

In recent years, we have seen that technologies have become intermingled with organizations to a great extent. It is rather difficult to even imagine a contemporary organization providing its services without the use of any technology. Ciborra's (2006) insightful work on risk management technologies shows that by investing in technologies that can do risk calculations, the risks and these technologies *imbricate*. That is, as the organization starts relying more on risk calculations, the risk calculation technologies themselves become a major source of risk. Indeed, the same seems to apply to business continuity. In any organization, there is also an imbrication of information systems and business continuity, as information systems are themselves a major source of failures, but simultaneously they contribute to *producing* business continuity.

IS scholars have convincingly established over the course of decades that the outcomes any technology produces are not inherent to the technology itself but are used differently across persons and contexts (e.g., Straub & Giudice, 2012). Technologies seem to be subject to a great deal of interpretive flexibility (Orlikowski & Gash, 1991). That is, any single technology is likely to be used (and produce) different outcomes in different contexts. In other words, technologies “are just ‘dead objects’: they get situated in the flow of organizational life only thanks to a mélange of human motives and actions” (Ciborra, 1999, pp. 85-86). Consequently, technologies in themselves are not likely to be solely responsible for business continuity but relational to how they are used and situated in context.

In what I have referred to as the social approach, business continuity pertains in social and cognitive processes. Butler and Gray (2006) have argued that technologies are *inherently* unreliable and only achieve veneers of permanence and stability through human ingenuity (i.e., when operated *mindfully*). They argue that the reliability of technologies—a precondition for business continuity—is dependent on what work is done and how it is performed. Perrow (1981) has famously studied large-scale breakdowns of complex socio-technical systems, such as nuclear power plants and infrastructures, and found that the tendency toward breakdowns is a “normal” part of these complex systems. Based on his arguments then, as infrastructures grow increasingly more complex and imbricate in new ways, we are likely to experience more, not less, breakdowns. Thus, the social processes, that Butler and Gray (2006) also emphasize, become the key to business continuity (see also Niemimaa, 2017). Indeed, Rapaport and Kirschenbaum (2008) have argued that business continuity is the outcome of social processes that lead to survival. However, these studies would suggest that the only limitations for business continuity are the boundaries of ingenuity facilitated by cognitive or social factors, which would seem to overshadow considerations over the limitations posed by *materiality*. After all, the mind is embodied, but the mind is also materially extended. (e.g., Barad, 2007)

2.2.3 Work practices and business continuity

Focusing (overly) on interpretive flexibility poses the risk of losing the technology from theories and explanations. Indeed, Orlikowski and Iacono (2001) argued that the IS discipline has lost the IT artifact. The lack of “matter” in IS studies is hardly surprising, as the same tendency seems to sweep across much of our reference disciplines (Dale, 2005) from where our theories mostly originate. By focusing overly on social and cognitive processes, the technology withdraws to the background. For instance, even if we know that a certain technology is *perceived* to be easy-to-use (like in the Technology Acceptance Model (Davis, 1989)), it tells little about the technology itself. Rather, the technology itself, as a material artifact, is implicated in how those perceptions become formed, and the matter constrains and enables what it can be used for, regardless of how it is perceived (c.f., Leonardi, 2011). A person may not wear his wife as a hat regardless of how strong his perception of the "wife-as-a-hat" is, or how novel and ingenious that use would be. Neither can a person have a (bidirectional) conversation with a fire post, no matter how strongly he perceives it as a real person[2]. In other words, possible uses would seem to reside not in the social nor in the material but in the ways they entangle. But how does any of this relate to business continuity?

The materiality of technology poses boundaries to how work is performed. These boundaries pertain to all work, whether it is about routinized work or moments of creativity, ingenuity, and improvisation. However, these boundaries are not fixed nor clearly identifiable. Pipek and Wulf (2009) refer to *in situ* design work through which new infrastructure innovations (i.e., new uses of infrastructure) emerge as infrastructuring. This idea of *in situ* infrastructural design is similar to what Johri (2014) calls as *sociomaterial bricolage* (see also Aanestad et al. (2014) for similar ideas). Infrastructuring, as a form of *in situ* design work, extends the possibilities of performing work by using the same technologies differently to accomplish a task at hand and/or by utilizing other appurtenances, even as simple as Post-it® notes (see Orlikowski and Scott (2008)) (I refer to this as the "workspace" in article #5). Thus, what can be achieved with a specific technology becomes enacted in relation to a specific task and on the totality of appurtenances available rather than given *a priori*. Consequently, determining *a priori* what any given organization's abilities are to withstand or to cope with disruptions is significantly challenging.

Work practices are constellations of humans, technologies, and material appurtenances (Orlikowski & Scott, 2008). To perform work is simply to create different configurations from these constellations. Orr (1996) showed through his detailed analysis of printer repairmen that the possibilities through which a printer failure becomes repaired emerge from a triangle constellation of the printer, the technician, and the customer. And when forming "right" constellations fails, performing the intended work fails. The work practices are thus highly contextual and contain "invisible" aspects that are significant for their reliable performance (Almklov & Antonsen, 2014). This brings the discussion back to the ideas embedded in business continuity management. To improve business continuity is to create opportunities for alternative constellations and, thus, expand the possibilities to perform work. Indeed, against this backdrop, the idea that improvements follow from trans-

[2] Both these examples originate from the famous and insightful case studies by the neurologist Oliver Sacks (1985). He has famously documented several rare perceptual impairments that illustrate the complex workings of brains. But they also vividly illustrate the constraints that matter places on our actions and ingenuity.

formations of work practices and routines (as discussed above) becomes intelligible. But simply recognizing this does not much improve our understanding on business continuity—especially in the infrastructure context.

Past IS research has seen *sociomateriality* as a fruitful foundation on which to study work that is entangled with infrastructures that are distributed across space (Almklov et al., 2014).

2.3 Sociomateriality

Zeno began by asserting the existence of the real world. "What do you mean by real?" asked the Sceptic. "I mean solid and material, I mean that this table is solid matter." "And God," asked the Sceptic, "and the Soul." "Perfectly solid," said Zeno, "more solid, if anything, than the table." "And virtue or justice or the Rule of Three; also solid matter?" "Of course," said Zeno, "quite solid." (Murray, 1915, p. 25)

Sociomateriality is a highly theoretical and abstract notion to draw attention to the relationship between the social and the material. Since information systems, as a discipline, is broadly concerned with the relationship between (social) organizations and (material) technologies (e.g., Walsham, 1993), it is not that surprising that sociomateriality has rapidly emerged as one of the viable theories to make sense of this relationship (Jones, 2014).

Leonardi and Barley (2008) describe the past theorizing as a pendulum swinging from technological determinism to social voluntarism and sociomateriality holding great promise in regard to stopping the swing. Sociomateriality, is not, however, any unified and singular view but best seen as an umbrella term that covers a diverse, and even partly incommensurable, theories that build on a broad range of philosophical underpinnings. I will discuss in the "Research Approaches" chapter the philosophical underpinnings on which I build my sociomaterial theorizing and focus here on sketching the ideas embedded in sociomateriality more broadly and on the empirical application of those ideas to relate the notion to my research endeavor.

From a theoretical perspective, sociomateriality can help researchers to see connections and surface relations and aspects that might have been missed otherwise. In other words, it provides a lens through which to analyze empirical phenomena and foundations upon which to build an inquiry. For instance, by building on sociomateriality, Scott and Orlikowski (2014) studied how anonymity becomes *performed* in social media, Schultze (2011) studied how (the materiality of) technology *performs* identities in virtual worlds, and Cecez-Kecmanovic, Kautz and Abrahall (2014a) studied how IS success becomes *performed* and determined by sociomaterial practices. These questions surface conceptions of anonymity, identity, and success that are qualitatively very different than traditionally conceived. They appear not as static representations that merely "are" but become performed through shifting/changing entanglements with matter. As such, sociomaterial theorizing is closely related to a practice lens, according to which "the specific outcomes of stability or change are seen as consequential only in the context of the dynamic relations and performances through which such (provisional) stability and change are achieved in particular instances of practice" (Feldman & Orlikowski, 2011, p. 1249).

2.3.1 Materiality and "social" inquiries

Barad (2003) has famously argued that "Language matters. Discourse matters. Culture matters. There is an important sense in which the only thing that does not seem to matter anymore is matter" (p. 801). Her argument well captures the felt dissatisfaction and insufficiency of theorizing from which sociomateriality emanates. The core of sociomaterial theorizing is to bring "materiality" to theorizing. It seeks to change the role of matter from an invisible and uninteresting substrate to a more performative and active role that partakes in how social practices manifest that "require an exhaustive recalibration of the fundamental categories that order social thought" (Jones, 1996, p. 291). Indeed, matter has gained such significant attention throughout the social sciences that some have asserted that a "material turn" is taking place (Coole & Frost, 2010; Bennett, 2009; Dale, 2005; Dolphijn & van der Tuin, 2012; Lemke, 2014). Given the technological and "infrastructured" nature of our work and life, focusing gaze on the material aspects of social practices feels rather cogent and aligned with our everyday experiences, as "it is only by working through the agencies of different things that humans accomplish anything" (Kipnis, 2015, p. 48).

Designating a more active role to matter leads intuitively to questions about agency. From a sociomaterial perspective, agency and ontology are interrelated concerns (Barad, 2007; Bennett, 2009; Coole & Frost, 2010). "Things are not just formed matter, they are transductions with many conditions of possibility and their own forms of intentionality" (Graham & Thrift, 2007, p. 3). Such position differs greatly from the conceptions that view agency as the sole and privileged attribute of the human individual (Jones, 1996; Rose, Jones, & Truex, 2005). In contrast, sociomateriality promotes a decentered, polycentric, and non-anthropocentric agency. This requires further elaboration; after all, as Knappett and Malafouris (2008) rhetorically put it, "[m]aterial and nonhuman agency—surely this is a mistake?" (p. ix).

2.3.2 Sociomaterial agency

Technology easily depicts behavior that is associated with agency. Modern (and also not-so-modern) technologies are capable of performing on their own. We have seen this, at least, since the steam engine. Modern IT technologies have, however, made this harder to ignore. Technologies transform work as they *automate* (Zuboff, 1988). Scheduled batch processes are run automatically, technologies call for maintenance as they self-diagnose wear and tear, and technologies independently make repair decisions as infrastructures break down. For instance, for years now hard drives have been able to self-diagnose their health and notify administrators of a possible risk of break down, and modern power grids automatically protect equipment and repair power outages much in the same way as modern telecommunications networks automatically recalculate and reconfigure routing information to bypass any faulty parts. It would thus feel tempting to take these as signs of autonomous actions and thus to conclude that modern technologies *have* agency. Such view of agency has been used in what Jones (2014) calls “weak” forms of sociomaterial theorizing that build on *critical realist* foundations. Previous IS research has used these weak forms of sociomateriality to analyze, for example, the formation of technological routines (Leonardi, 2011) and the social implications of plagiarism systems (Introna & Hayes, 2011). However, “in any practical situation, we always have an agency stew. It is hard to tell where the agency is: some of it is in the carrots (people), some of it is in the potatoes (things), and some of it is in the sauce (protocols, languages, etc.). You can pick it apart, [it] but it would not be the same dish” (Pentland & Singh, 2012, p. 289). Alternative ways of understanding material and non-human forms of agency exist that seem particularly well-apt to deal with issues pertaining to infrastructures. These build on “strong” forms of sociomaterial theorizing (Jones, 2014) founded on relationalist (Emirbayer, 1997) conceptions of agency.

A key tenet of relationalist conceptions is that “agency is widely distributed, and inheres in the relationships between the various entities that constitute a field of action” (Knappet, 2002, p. 100). Agency is no longer a designated attribute/property of any single individual human or a “thing” but pertains in the flux of the ever-changing network of relations. Numerous theoreticians have commented on the topic and brought forth different variations of this same fundamental idea (e.g., Cooren, 2015; Pickering, 2008; Kipnis, 2015; Latour, 2005). I will limit the discussion here mostly to Karen Barad’s conception, as she has profoundly influenced the “strong” forms of sociomaterial theorizing in IS (Leonardi, 2013; Mutch, 2013; Scott & Orlikowski, 2013), which forms the foundations of this dissertation[3].

[3] Barad’s work is highly abstract and philosophical, and she employs descriptions that are full of neologisms (e.g., “intra-action,” “agential cut,” “(re)configuration”), zeugmas (e.g., “matters that matter”), and even tautologies (e.g., “sociomaterial entanglement”). I have sought to keep the “jargon monoxide” (Kautz & Jensen, 2013) here to a minimum. For more elaborate discussion on the foundations, see article #3.

Readers who are familiar with actor network theory (e.g., Latour, 2005) will likely find similarities between these two conceptions. Gond, Cabantous, Harding and Learmonth (2015) argue that the difference between these two stances lies in Barad's more radical stance on materiality that is derived from quantum physics and that she views non-human and human elements both as made of matter. While Barad does derive her view from quantum mechanics, one of the important points missed by Gond et al. (2015) is, that they themselves enact a preexisting dichotomy that clearly separates human and non-human elements (and defines that both *are* made of matter). Barad herself contests any preexisting differentiation between the two and, instead, criticizes actor network theory for making such a clear attributions. She views that such attributions may hid political assumptions and oppressive practices and thus we should maintain sensitivity in how we enact these categories and attribute "things" with human or non-human qualities through our practices (see also Barad, 2007, p. 215).

From the strong sociomaterial stance, "*social* and *material* are each simply selective projections of a tangled whole" (emphasis theirs)(Mazmanian et al., 2014, p. 832). This entangled whole is what Barad (2007) refers to as "phenomenon." Phenomena are, however, not specific aspects of the world but constellations of social and material agencies that are non-existing outside of their entanglement. "This view suggests that the social and material entities that make up IS have no absolute essence when viewed in isolation, but that their collective force defines the agency of IS" (Mahama et al., 2016). This might sound at first rather counterintuitive, as we tend to take the existence of individual things as constitutive of our reality. When agency inheres in the relations, the space of possibilities for action (Pentland & Singh, 2012) is not determined solely by any individual but congeals temporarily only in relation to the whole of things that constitute a particular situation and practice (Barad, 2007). "[W]hat is at stake is not the locus of agency, but rather the question of how 'arrangements that produce effective forms of agency' (Ibid.[Suchman, 2007], p. 242) emerge in ongoing work" (Mazmanian et al., 2014, p. 832). As such, the relationalist view also questions the existence of transitive stable and persistent social structures, and rather argues that the structures inheres in situation-specific sociomaterial configurations. Simply put, when hammering a nail into a wood, the agency is not inherent in the hammer any more than it is in the person hammering. Instead, agency inheres in the specific arrangement of the constellation of the hammer, the hammerer, the nail, the wood, and so on. Indeed, "[t]here was never a time when human agency was anything other than an interfolding network of humanity and nonhumanity; today this mingling has become harder to ignore" (Bennett, 2009, p. 31). Much of this pervasive mingling seems to relate to the increasing infrastructuring of our lives; we live in the nexus of infrastructures that are embedded in infrastructures.

Mazmanian et al. (2014) provide an excellent empirical account of such sociomaterial agency in IS research. Building on Barad's (2003, 2007) concept of reconfiguration, they use it to denote "the *process* in which new assemblages of agency emerge" (emphasis theirs) (Mazmanian et al., 2014, p. 832). Reconfiguration provides them conceptual tools to trace the process in the NASA space exploration mission environment. For the technicians operating the space craft, "numbers on a screen, simulations of the craft, and navigational charts are key figures in the sense that they provide the capacity to visualize and manipulate the distant craft and make a completely virtual environment (space) amenable to action" (Ibid., p. 833). Building on rich ethnographic material, they conclude that their "analysis suggests that the relationships between the various dimensions of any sociomaterial analysis are forever in action, and interaction" (Ibid., p. 847).

As Mazmanian et al. (2014) show, the technicians' infrastructure used to manage and control the space craft is an assemblage in which dynamic and polycentric fields of action emerge. But if agency is in perpetual flux, and congeals only temporarily, it would then seem to defy the relative stability and permanence as experienced in our daily lives. Indeed, Barad (2007) explains this relative stability and permanence with history—matter is historical and constraining. The history is constraining such that not everything or anything is possible at any time but is relational to what has taken place before. Matter carries the traces of its becoming, and this history limits possible future development trajectories. That is, matter itself has an agentive role in its own becoming. This is what she means by arguing that matter does not unfold but rather *enfolds*; matter unfolds by unfolding *through* itself. She illustrates this with an example: "[a]s the rings of trees mark the sedimented history of their intra-actions within and as part of the world, so matter carries within itself the sedimented historalities of the practices through which it is produced as part of its ongoing becoming—it is ingrained and enriched in its becoming"[4] (Barad, 2007, p. 180). Indeed, for Venters et al. (2014), matter's history is part of the dynamics of agency that shape infrastructures' use and development. However, there is one important aspect of agency that has not yet been discussed—the discontinuity of matter and its significance for agency.

Matter is always unpredictable, or *discontinuous*, as Barad (2007, 2010) refers to it. This view is also shared by Bennett (2009), who views matter as *aleatoric*. For them, the dynamics of matter defies strict determinism that affords complete predictability as viewed by "clockwork" (i.e., mechanistic) models of reality. Barad (2010) elaborates, "if the indeterminate nature of existence by its nature teeters on the cusp of stability and instability, of possibility and impossibility, then the dynamic relationality between continuity and discontinuity is crucial to the

[4] Barad (2007) underscores several shortcomings of this metaphor, and as such the example should not be taken literally as a representation but rather as an evocation and provocation to think with. See Barad (2007, pp. 181-182) for an elaborate discussion of the limitations. However, the metaphor serves here to merely illustrate the processual nature of matter.

open ended becoming of the world which resists acausality as much as determinism" (p. 248). What follows is that "[c]hanges do not follow in continuous fashion from a given prior state or origin, nor do they follow some teleological trajectory—there are no trajectories" (Barad, 2007, p. 181). Incorporating the discontinuity of matter questions the regulative ideal of agency "as the accurate translation of ideas into effects" (Bennett 2005, p. 453) that "chafes against everyday experience—where it seems that one can never quite get things done, where intentions are always bumping into (and only occasionally trumping) the trajectories of other beings, forces, or institutions" (Bennett, 2005, p. 453). Law and Mol (2008) elaborate this:

> What each actor does also depends on its co-actors, on whether they allow it to act and on what they allow it to do, on rules and regulations. But this is not to say that an actor-enacted is determined by its surroundings. It has its own stubbornness and specificities: it is full of surprises. So the difference an actor makes is not predictable. (Law & Mol, 2008, p. 73, in Knappett & Malafouris, 2008)

Thus, it seems that conception of agency needs to recognize the inherent unreliability of matter to act upon and with, which is an especially pertinent characteristic when dealing with complex infrastructures (c.f., Bennett, 2005). So what does all this discussion on agency mean for infrastructure continuity? How should we understand it in light of the provided discussion on prior literature on infrastructures and business continuity?

2.4 Performing infrastructure continuity

In the previous sections, I have sought to enact new and foreground old relations between various thinkers that cut across many disciplinary boundaries. Next, I will integrate the discussions and elaborate what it all means to infrastructure continuity. In doing so, I will outline ideas on a performative view of business continuity. While I present these ideas here, they are not merely a result of reading and analyzing prior literature but have resulted through iterative reading of literature and empirical material that has taken place during the course of this dissertation research (see "3.3: Ethnographic fieldwork").

Infrastructures are not just technological or social but heterogeneous constellations of human and non-human agencies distributed across space and time. Bennett (2005) describes the constitution of a power grid as "a volatile mix of coal, sweat, electromagnetic fields, computer programs, electron streams, profit motives, heat, lifestyles, nuclear fuel, plastic fantasies of mastery, static, legislation, water, economic theory, wire, and wood—to name just some of the actants" (p. 448). Infrastructures are, thus, evolving pluralities of entangled human and non-human agencies—that is, sociomaterial constellations. As sociomaterial constellations, infrastructural failures cannot be explained simply in terms of the social or the technological (material) but need to be attributed to the temporary arrangements/configurations they form in practice. A key question then is how effective forms of agency emerge in ongoing work through which infrastructure continuity becomes performed. That is, it calls for studying what work is done and how it is performed (Butler & Gray, 2006).

As discussed, smart infrastructures form a context for performing work. These contexts are often also critical for societies, as they form the backbone through which electricity is distributed, water is delivered and wastewater removed, people are transported (e.g., road and railroad infrastructures), and so on. Agency, when situated in a smart infrastructure context, seems to relate to four mechanisms that shape the ways in which practices manifest as actions. These four mechanisms relate to the

- History of the infrastructure,
- Polycentric and agentic constitution,
- Dynamic and invisible agencies, and the
- Discontinuity (and aleatory) of matter.

I have conceptualized these mechanisms collectively as *infra-acting* possibilities that account for the reciprocity of action and the materiality of infrastructure.

The mechanisms are not perceptual in such a way that their implications would depend on cognition. Rather, they are what Barad (2007) refers to as *onto-epistemological*. Moreover, these mechanisms do not *determine* behavior but form a (dynamic) space of possible actions. As such, they resemble Pentland's (2013) grammars of action, "which generate a space of possible behaviors, from which actants can construct particular behaviors. Similarly, English grammar does not determine what sentence you will say or write next" (p. 9). He thus proposes focusing "on the actions and patterns of action that are enabled and constrained by information and communication technologies (ICTs)" (p. 8) rather than on the IT artifact or human agencies.

Infra-acting provides a lens for analyzing the patterns of actions to study how infrastructure continuity becomes performed. After outlining the research approaches of this study, and providing summaries of the articles that constitute this dissertation, I will provide an illustrative empirical study to surface a performative account of business continuity in a smart infrastructure context.

3 RESEARCH APPROACHES

In this chapter, I will outline the research approaches adopted in this dissertation. I have used two different research approaches through which the findings of this dissertation have materialized. First, I have built on a literature review to understand the foundations of business continuity research. Second, I have applied ethnography as an empirical approach to study the phenomenon of infrastructure continuity in practice. But before outlining the details of these research approaches, I will provide a discussion on some philosophical considerations for this study.

3.1 Philosophical considerations

Thrasumachus: Childish and altogether ludicrous is what you yourself are, and all philosophers; and if a grown-up man like me spends fifteen minutes with fools of this kind it is merely a way of passing the time. I've now got more important things to do. Good-bye! (Schopenhauer, 1970/1850, pp. 50-51)

All research embodies a certain set of assumptions that render certain aspects of the world more salient than others. These methodological concerns (Cecez-Kecmanovic, 2011) can be expressed in terms of philosophical worldviews that form perspectives through which particular problems become visible and questions emerge meaningful (e.g., Orlikowski & Baroudi, 1994). The philosophical perspective is thus foundational to any research endeavor. I have founded my research on realist foundations, albeit on a very distinct and peculiar sort of realism—on agential realism. After providing a broader discussion on the prevailing perspectives in IS, I will elaborate agential realism and especially its relation to knowing. The broader discussion aims to surface some of the key aspects of the prevailing perspectives from which agential realism departs.

3.1.1 Prevailing philosophical perspectives in information systems

Owing perhaps to the emphasis on the instrumentality of much of the sciences these days, the intimate relation between science and philosophy has become rendered less visible and salient, which chafes against the fact that, after all, "Science, with a capital S, is an invention of philosophers" (Fuchs, 2009, p. 6). The instrumentality, or what Bertrand Russell (1945) calls the practical science, is a rather recent tendency in the overall historical trajectory of philosophy and science:

> The practical importance of science was first recognized in connection with war; Galileo and Leonardo obtained government employment by their claim to improve artillery and the art of fortification…The triumph of science has been mainly due its practical utility, and there has been an attempt to divorce this aspect from that of theory, thus making science more and more a technique, and less and less a doctrine as to the nature of the world. (p. 493)

In contrast to practical science, theoretical science "is an attempt to *understand* the world" (emphasis his) (Russell, 1945, p. 492). As I have indicated in the purpose of the research (see "1.2: Purpose of the research and research questions"), this research falls into this latter category.

Producing knowledge poses concerns over the nature of "the world" that we seek to understand and over the ways in which we know about its nature. These concerns relate to *ontology* and *epistemology,* respectively. The natural sciences, and their social sciences counterpart positivism (Benton & Craib, 2001), have traditionally focused on capturing through rigorous methods the true and objective ontological nature of the world as conceptual (and mathematical) representations. Barad (2010) elaborates this view in her ironic way:

> Calculus is revealed as the escape hatch through which Man can take flight from his own finitude. Man's reward: a God's eye view of the universe, the universal viewpoint, the escape from perspective, with all the rights and privileges accorded therein. Vision that goes right to the heart of matter, unmediated sight, knowledge without end, without responsibility. Individuals with inherent properties there for the knowing, there for the taking. Matter is discrete, time is continuous. Place knows its place. Time too has its place. Nature and culture are split by this continuity, and objectivity is secured as externality. We know this story well, it[']s written into our bones, in many ways we inhabit it and it inhabits us. (p. 249)

That is, the world awaits its discovery by the ingenious scientists through the scientific method that yields results that are often expressed with mathematical precision. Or as the Pope put it: "Nature and Nature's law lay hid in Night. God said, 'Let Newton be!' and All was Light" (Pope in Collier, 1994, p. 238). The scientific method and its precise following gains priority over philosophical concerns. Indeed, in IS research those relating to the positivist perspective of the field are often freed from the requirement to elaborate their foundational assumptions.

The natural science mode of scientific inquiry has been troubled and attacked from many sides, especially in the social sciences, to which this IS research also belongs. For the sake of simplicity, I refer to these collectively merely as an "interpretive" perspective, as has been customary in the IS literature (Orlikowski & Baroudi, 1991; Chen & Hirscheim, 2004). The domain of the social is said to be distinct from the natural world, thus enacting a duality of the "natural" and the "social." While some of the proponents of the interpretive perspective deny any and all possibilities for an unmediated and objective knowledge arguing for the social construction of the whole physical world (Barnes, 2004), others recognize that these issues pertain especially to social inquiries. As Lincoln, Lynam and Guba (2011) elaborate, "if knowledge of the social (as opposed to the physical) world resides in meaning-making mechanisms of the social, mental, and linguistic worlds that individuals inhabit, then knowledge cannot be separate from the knower, but rather is rooted in his or her mental or linguistic designations of that world" (p. 176). That is, all knowledge is said to be relational to our preconceptions and prejudices—in other words, *mediated* through our senses and cultural influences[5]. Or as Sören Kierkegaard put it in Latin, "Quicquid cognoscitur, per modum cognoscentis cognoscitur"[6].

A specific trait of the social sciences is to be found from the target of our inquiries. Where the nature is taken as passive, and unreflective, the social is active, and reflective. The prominent German philosopher Hans-Georg Gadamer (2004), whose work has broadly influenced IS research (Klein & Myers, 1999; Mingers & Willcocks, 2004), describes this reflectivity and understanding in terms of hermeneutics. According to hermeneutics, any understanding proceeds in cycles of interrelating parts within a whole that, in the case of social interaction, is said to lead toward the merging of horizons that never fully merge (i.e., a degree of "Otherness" always remains). To state the same in simpler terms, what Gadamer (2004) says is that we seek to understand each and every word and sentence in relation to the whole of what is being communicated (whether verbally or other means) until understanding emerges. This cycle is neither voluntary nor methodological but rather an orientation toward the world, a sort of a primordial condition of understanding and being in the world (Gadamer, 2004). However, this stark distinction between the social and the material prevalent in the interpretive perspective can explain the relative lack of attention to materiality in the social sciences (Dale, 2005). In IS research, critical realism (CR) has gained increasing popularity and seeks to provide a way to reconcile (or at least bridge) the positivist and interpretive gap (Mingers, 2004)—to find the *tertium non datur* (Stahl, 2007). The focus here is to briefly outline some of the central ontological and epistemological tenets of CR.

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[5] For instance, the famous duck/rabbit painting (see Jastrow (1898) for the original illusion) demonstrates how we only see either a duck or a rabbit depending on our preconceptions and that we always only see one of them at a time.

[6] "Whatever is known, is known in the mode of the knower."

CR acknowledges that that knowledge is always mediated through our senses and experiences but preserves the possibility of an objective world. That is, recognizing that our knowledge of the world is mediated does not necessarily tell anything about the nature of the world. It only means that we should account for the distortions our senses add to the knowledge. Separating the knowledge from the object of the knowledge is said to overcome the *epistemic fallacy* prevalent in interpretive perspective (Mingers 2004). Despite the epistemic subjectivity, the ingenious and reflective subject, the researchers, can induce objective claims about the world that explain the observed phenomenon. Nevertheless, as the world "out there" is never directly observable, but only inducible from observations and experiences, the knowledge is always partial and fallible.

What this lengthy passage on the prevalent philosophical perspectives in IS aims to show is the shared commitment to the dichotomy of the self and the world. This separation is already reflected in the very duality of ontology *and* epistemology. What could our understanding of the world be like if this duality were to be rendered visible and then interrogated? Or what if, instead of interrogating this specific duality, we start "interrogating the very idea of duality?" (Woolgar, 2002, p. 268). How should we then understand the taken-for-granted dualities of nature and culture, social and material, material and immaterial and so forth? This is what agential realism seeks to establish.

3.1.2 Agential realism

Words are but symbols for the relations of things to one another and to us; nowhere do they touch upon absolute truth… Through words and concepts we shall never reach beyond the wall of relations, to some sort of fabulous primal ground of things… It is absolutely impossible for a subject to see or have insight into something while leaving itself out of the picture, so impossible that knowing and being are the most opposite of all spheres. (Nietzsche, 1998/ca. 1870, p. 83)

Agential realism builds largely on the works of Karen Barad (e.g., 2003, 2007, 2010). Her somewhat radical philosophical perspective has emerged as a potentially viable stance for IS research and has become associated with the "strong" form of sociomaterial theorizing (Jones, 2014). Or, as I have referred to it, it is the "radical" perspective to sociomateriality (see also Ramiller, 2012; Robey et al., 2013), as it reworks many of the foundational assumptions that have become taken for granted and rendered beyond questioning. I have covered agential realism more broadly and the theoretical and analytical "tools" it provides in articles #3 and #4 and focus here on elaborating its foundational assumptions on knowledge and its suitability for this particular research endeavor.

In contrast to given and fixed dualities, Barad posed the question: *What if the nature of the world and our knowing is that of entanglement and not of discreteness?* From this position, the duality of ontology and epistemology is not a given dichotomy but one that becomes enacted in/through practices. Instead of the duality, she suggests turning our gaze to "the study of practices of knowing in being" (Barad, 2007, p. 185)—that is, to the study of onto-epistem-ology. Onto-epistemology is thus concerned not with transcendence but with *immanence* (i.e., with the possibilities of our knowing). Overall, her philosophical perspective shares many similarities with that of practice theorists (Feldman & Orlikowski, 2011) but also with network ontologies such as Actor-Network-Theory.

Rather than viewing knowledge as some form of frozen and static representation of a particular aspect of the world, agential realism takes the stance that knowledge is tied to the practices of knowing. Emirbayer (1997) refers to this distinction as the duality between *substantialist* and *relationalism* (or transactionist). "The key question confronting sociologists in the present day is not 'material versus ideal,' 'structure versus agency,' 'individual versus society,' or any of the other dualisms so often noted; rather, it is the choice between substantialism and relationalism" (p. 282). Where substantialists seek the essentials (i.e., "that things are what they are because that is their nature, essence, or definition" (Fuchs, 2009, p. 3), relationalists follow the stance that there is no world that is clearly demarcated into isolated and discrete "things" that await discovery and conceptual representation. Instead "what things [are] they are for an empirical observer, and what these things can do depends on how they are related to things of a similar sort" (Fuchs, 2009, p. 3). Engagement with the world precedes any "things"; to know a "thing" is to engage with the world. That is, through our engagement with the world the world receives its boundaries, things receive their properties, and concepts receive their content, simultaneously (Rouse, 2004). "Language does not name objects in the world; it is core to the process of constituting objects" (Deetz, 1996, p. 192). This stance, according to which any "things" [7] or "technologies do not stand alone with certain inherent properties, but that their material characteristics and capabilities are relevant only in relation to specific situated practices, can be hard to grasp" (Feldman & Orlikowski, 2011, p. 1249). Thus, in lieu of representations, the focus is on the practices through which knowing becomes achieved.

Practices of knowing are not merely discursive but inherently material (i.e., "material-discursive" (Barad, 2007)). "Making knowledge is not simply about making facts but about making worlds, or rather, it is about making specific worldly configurations—not in the sense of making them up ex nihilo, or out of language, beliefs, or ideas, but in the sense of materially engaging as part of the world in giving it specific material form" (Barad, 2007, p. 91). In the case of, for

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[7] Strictly speaking, there are no "things" in agential realism. Hence in lieu of "things-as-part-of-phenomenon" I use "things."

instance, virology, such is rather intuitive. The practices of seeing a virus are thoroughly entangled with the sophisticated technologies that *produce an image* of the virus that could not be made visible without these technologies. The electron microscopes used to "see" viruses are not merely magnifying glasses but complex technologies that require careful preparations of the instrument and the specimen in order create the image of a virus; to see a virus is to (re)produce the expected patterns under certain circumstances. But the same applies to the studies of what we take as the social aspects of the world.

The way in which we engage with informants and the "tools" (whether methodological or material) we use in our engagement become a part of the process of the knowledge inquiry. Knowing is thus contextual and contingent upon the ways of knowing. Our methodological choices define how we engage with the world and the knowledge we produce but often also define the (material) context of our engagement and interaction. This is what Hammersley and Atkinsson (2007) mean when they say that experiments and interviews may lead us "to discover only how people behave in experimental and interview situations" (p. 9). When engaging in knowing, we, as scholars, are therefore already, and inescapably, a part of the world that we seek to explain. However, this is not to say that the researcher could solely determine what is seen or how a particular phenomenon materializes. Rather, it is to indicate that whatever is being observed is relational to the particular sociomaterial configuration that constitutes a particular situation—including the researcher. Knowing emerges through engagement and participation as a gradual and developmental activity (Ingold, 2014). Thus, knowing requires "focusing attention on the consequentiality of everyday action and the relationality of phenomena" (Feldman & Orlikowski, 2011, p. 1248) "that *produce* organizational reality" (emphasis mine) (Ibid., p. 1250).

Agential realism provides coherent philosophical grounds and theoretical "tools" for studying organizational sociomaterial practices (Orlikowski & Scott, 2008; Scott & Orlikowski, 2014). For the purpose of this research, agential realism provides foundations for understanding and explaining infrastructure continuity as performed in/through practices/technicians' actions in this specific material and technologically enabled context that smart infrastructure forms.

3.2 Literature review

To uncover what has been written about business continuity in general, in article #1, I conducted a literature review. Literature reviews are useful for summarizing current knowledge on a certain topic, which can then guide future development. Literature reviews result from a process of collecting articles and then analyzing them to come up with concepts and categories that organize the past to pave the way for the future (Webster & Watson, 2002).

The articles included in the literature review were the outcome of a process whereby I first searched for the term "business continuity" from the leading journals of the IS field (Webster & Watson, 2002) and then expanded the search to well-known search engines (Google Scholar, ACM Digital Library, ProQuest, AIS Digital Library, and EBSCO). The search included only peer-reviewed journals and articles that included business continuity in regard to topic and/or abstract to limit the search to a manageable number. The collected articles were then briefly analyzed to prune out articles that were dealing with non-IS related topics (e.g., pandemics) or were not interested in business continuity in an organizational context. As I realized during this literature analysis, business continuity is a multidisciplinary interest that is spread across several disciplines.

The multidisciplinary nature of the literature posed some difficulties, as the research published in other disciplines might not always follow the explicit and implicit "rules" of the IS discipline, for instance, in their use of prior literature, methodologies, or theory. As such, analyzing the cumulative development or theoretical contributions of the studies was not really a feasible option, as there did not seem to be any common literature or theory basis shared across the studies. To bring the multidisciplinary scholars into discussion, and propose an integrative framework, I used *hermeneutics* as a way of gaining an understanding of that which is unfamiliar and alien.

Hermeneutics, as I have explained above (see "3.1.1: Prevailing philosophical perspectives in information systems"), is seen in philosophy as an orientation toward the world, but it can also be seen as a method (Lee, 1994; Myers, 2004; Boell & Cecez-Kecmanovic, 2014). While the history of hermeneutics lies in the exegesis (Gadamer, 1984), it has become a way of interpreting all kinds of texts and text analogues (Klein & Myers, 1999). Hermeneutics poses, paradoxically, that correct understanding emerges from interrelating parts with the whole and the whole with the parts. "The nearest analogy is first walking all over a mountain in a mist, until every path and ridge and valley is separately familiar, and then, from a distance, seeing the mountain whole and clear in bright sunshine. This experience, I believe, is necessary to good creative work" (Russell, 1945, p. 124). Following the methodological principle of hermeneutics, I sought to soak myself in the details of the uncovered articles and noted down ideas on the broader themes the articles cover. These categories were then related to the individual articles and the categories adjusted in relation to the particulars until sufficient abstractions were extracted. Through these iterations I enacted analytical categories to organize the literature into themes.

3.3 Ethnographic fieldwork

I have endeavored to show that there is no sovereign method for establishing fieldwork truths. It is murky out there and in here. (van Maanen, 2011a, p. 138)

The empirical part of this study resulted from ethnographic encounters with informants over a prolonged period of time. The fieldwork for the ethnographic research took place between October 2014 and June 2015 (2-3 days a week with some exceptions due to holidays, etc.). The resulting empirical material provides the foundations for the articles #5 and #6. In the conduct of the research, I have built on methodological guidance on sociomaterial ethnographies as outlined in article #3 and on more general guidance on naturalistic inquiries (see “6.5: Considerations for the evaluation of the quality of the study”). I will next provide a brief overview of ethnographies in general and provide my rationale for engaging this specific mode of inquiry. After providing the rationale, I will describe the process of inquiry and outline what kind of empirical material it yielded.

Ethnography, as a naturalistic inquiry, is one of the most in-depth research approaches (Myers, 1999); “Fieldwork of the immersive sort is by and large definitional of the trade” (van Maanen, 2011b, p. 219). It is a peculiar type of scientific inquiry yet founded on the same premises as the most natural and intuitive forms of understanding in our everyday life: “in the conduct of our research, we [ethnographers] meet people. We talk with them, we ask them questions, we listen to their stories and we watch what they do. In so far as we are deemed competent and capable, we join in” (Ingold, 2014, p. 386).

The ethnographer is expected to join the “natives,” “taking close to the same shit others take day-in and day-out (or, if not taking it directly, hanging out with others who do)” (van Maanen, 2011b, p. 220), and after a lengthy fieldwork period come back with good stories and insights into their lives. It is no wonder that “[b]oth the novelty of the paradigm and the strangeness of the reporting format pose special problems for editors and referees of journals, peer review committees or dissertation committees considering proposals, and naturalistic investigators themselves as they attempt to design and monitor their inquiries” (Guba, 1981, p. 75). Quite obviously, some of the novelty and strangeness of ethnography has certainly disappeared since Guba made his argument, and some methodological guidance has also appeared (e.g., Klein & Myers, 1999; Walsham & Sahay, 1999; Myers, 1999). Nevertheless, ethnographers have sought to maintain their distinctiveness, as Ingold (2014) well illustrates: “Such a procedure, in which ethnographic appears to be a modish substitute for qualitative, offends every principle of proper, rigorous anthropological inquiry—including long-term and open-ended commitment, generous attentiveness, relational depth, and sensitivity to context—and we are right to protest against it” (p. 384). But if such is the case, then why did I choose this particular approach that seems so defiant of the canonical modes of scientific inquiry?

Ethnography seemed an intuitive way of gaining insight into others' lives. Through my rather extensive industry experience as an expert and a consultant, I knew that developing an understanding of the work and the sociomaterial context of others can be a daunting task and require numerous close encounters with the informants, to whom the context appears less strange. According to Klein and Rowe's (2008) supervisory experience, doctoral students with extensive industry background, in most cases, "have conducted case studies based on in-depth interviews or conventional ethnographies" (p. 681). They reason that this is likely due to "their preunderstanding of the kind of data they needed and could collect" (Klein & Rowe, 2008, p. 681). Indeed, right from the beginning, I felt that organizations are best understood from within.

By underscoring the immersion to study context and the naturalistic process, ethnography provided the most suitable approach for the purpose of this research. The perceived distance, detachment, and artificiality of settings that underpin, for example, formal interviews are in ethnography replaced with a naturalistic setting, close encounters, informal interactions, and rapport. But most importantly, ethnography felt most appropriate for the proximal analysis of technicians' work, which can be difficult through other means, as "most work practices are so contextualized that people often cannot articulate how they do and what they do unless they are in the process of doing it" (Barley & Kunda, 2001, p. 81). Thus, gaining insights into how the technicians actually perform would not have been possible through more distant forms of research inquiries such as interviews or surveys. In addition, previous research has found ethnography particularly suitable to studying infrastructures (e.g., Star & Ruhleder, 1996) and sociomateriality (e.g., Leonardi, 2011; Østerlie et al., 2012; Mazmanian et al., 2014). As such, the choice of ethnography was supported by intuition, past experiences, and rational choices drawn from the literature.

As can be inferred from above, there is no single way of doing ethnography. Indeed, van Maanen (2011a) argues that "ethnography is still a relatively artistic, improvised, and situated form of social research where the lasting tenets of research design, theoretical aims, canned concepts, and technical writing have yet to leave a heavy mark" (p. 175). In other words, there are no "cookbooks" for doing ethnography, but rather "[o]ne becomes an ethnographer by doing it" (van Maanen, 2011b, p. 219).

What ethnography is, is one of the actively debated areas among anthropologists and organizational ethnographers (van Maanen, 2011b; Ingold, 2014). For me, ethnography signals the commitment to do lengthy and immersive fieldwork and is also a matter of (writing) style (c.f., Jarzabowski et al., 2014). While the strict page limits of conference articles have posed limitations on the style, I have adopted a more reflective style here when describing the empirical material (“3.3.1 Empirical material”) and the empirical site (“4 Empirical site: SmartGrid Co.”). Such style connects well to agential realist foundations, as the knowledge and practices of knowing are inseparable. Being reflective may draw criticism and raise concerns over the objectivity of one’s work. After all, “[m]uch of our writing is washed by a thick spray of claimed objectivity since artful delights and forms are seen by many if not most writers (and readers) in the field to interfere with the presentation of what is actually there in a given social world” (van Maanen, 1995, p. 134). However, being reflective opens opportunities for others to learn and reflect, and it also increases the transparency and trustworthiness of the research that are both important factors of high-quality ethnographic work (Guba, 1981). I will discuss the quality aspects more thoroughly under a separate heading (see “6.5: Considerations for the evaluation of the quality of the study”).

3.3.1 Empirical material

The men who founded modern science had two merits which are not necessarily found together: immense patience in observation, and great boldness in framing hypotheses. (Russell, 1945, pp. 527-528)

As is typical for ethnography, the empirical material is based on an extensive study of a single site (Hammersley & Atkinsson, 2007). I will provide a detailed description of the empirical site under a different heading (see “4 Empirical site: SmartGrid Co.”) and focus here on the process and the practices through which the empirical material was jointly created.

Early in 2013, I started charting opportunities for a more detailed and longitudinal study. I had discussions with people in different positions who I assumed would have good visibility into what was happening in different fields and organizations in relation to business continuity in general. These people matched well with Cook and Crang’s (1995) suggestion to start a study by negotiating with “gatekeepers.” Through these discussions, the Finnish power distribution sector emerged as a viable and interesting opportunity through which to learn more about the topic due to recent changes in legislation. These legislative changes required the power distribution companies to invest in ensuring their operations were compliant with a government-mandated business continuity framework. I expected the power distribution companies to provide an interesting setting for studying and learning about business continuity, as they are critical organizations for the whole society.

Negotiating access is one of the challenging tasks and is especially challenging when the topic deals with business continuity-related matters that organizations often consider to be confidential. Indeed, willingness to participate was one of the key requirements for choosing a site (Walsham, 2006). But in addition, the company had to be large enough to be a meaningful site for the purpose[8] and located physically close enough so that it would be feasible to commute there frequently. By October 2013, after different dead ends, I was able to negotiate access to one of the Finnish power distribution companies to observe their efforts in evaluating their compliance with the government-mandated framework. These efforts unfolded through a series of eight meetings that took place between October 2013 and June 2014. During this period, I also had the chance to be educated on the information systems they use and to attend to trainings where some of their most pertinent continuity challenges were discussed. While these meetings and other activities certainly had an influence on my broader understanding of the context, more importantly, they became decisive in regard to the further course of this study.

As a qualitative researcher, I sought to maintain openness to shift or even reconsider the focus of the study as new understanding emerged. The meetings felt artificial such that they were disconnected from the actual "real" work that the organization does and from the actual work that is invested to ensure that the electricity flows in the grid. Reflecting on it now, this should not have been a surprise. After all, the need for compliance was externally stipulated rather than internally recognized. My initial feelings were reinforced by the head of the operations at SmartGrid Co., who shared his expertise with me and explained that infrastructure continuity should not be something excess, not an additional procedure or a process, but has to be embedded in the work—in the everyday practices and doings. These observations necessitated that I broaden my perspective from the narrow conception that I had implicitly adopted of what business continuity is and start asking more broadly "'What is going on here?' or 'What do the natives think they are up to?'" (Alvesson & Kärreman, 2007, p. 1270). I started questioning some of my preconceptions and prejudices according to which business continuity is an outcome of the frameworks rather than of the work. I had clearly adopted this mentality during the period I worked as a management consultant, as such frameworks provide an authoritative voice to managing business continuity in organizations and are thus an indispensable "tool" for consultants (c.f., Siponen & Willison, 2009). Gradually, the idea matured, and I successfully negotiated access to the operations center of SmartGrid Co. to study closely how they actually perform their work. I was awarded with an opportunity to follow in the footsteps of some of the prominent organizational ethnographers who have studied technicians' work

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[8] I do not wish to indicate that small companies would not be meaningful to study just because they are small. However, as I learned during the process of finding a suitable research site, some of the power distribution companies are so small that they have only one person responsible for evaluating their compliance.

(e.g., Orr, 1996; Barley, 1996; Zuboff, 1988) but in a contemporary and IT-enabled infrastructure setting.

Approximately a year after my initial contact with the company (in October 2014), I started a period of participant observations at the operations center of SmartGrid Co. This period forms the empirical foundations for the findings of this dissertation. Participant observation is one the most distinguishing aspects of ethnographic research (Hammersley & Atkinsson, 2007; Myers, 1999; Ingold, 2014). What it merely signals is that "[t]he ethnographer participates, overtly or covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, asking questions; in fact collecting whatever data are available to throw light on the issues with which he or she is concerned" (Hammersley & Atkinsson 2007, p. 2). Further, participant observation was well-fit to the agential realist foundations of this study. As knowing is a practice, then engaging and interacting with the technicians is a way of coming to know. "For to observe is not to objectify; it is to attend to persons and things, to learn from them, and to follow in precept and practice" (Ingold, 2014, p. 387).

In practice, being a participant observer meant that I stayed in the operations center with the technicians two to three days a week (between October 2014 and June 2015) and mostly during office hours. I listened to their stories (and shared mine), eavesdropped on their conversations (and joined in when I could), drank many cups of coffee and ate several lunches with them, asked simple (and probably stupid) questions (and provided answers when asked), watched as they performed their work, and tried to comprehend why they acted the way they did.

Studying infrastructure environments, where the site of the study is distributed and mediated, poses some challenges for ethnographic research (Star, 1999; Beaulieu, 2010). Ethnographers have traditionally been skeptical towards mediated environments as direct interaction and rapport are seen to be necessary conditions for quality ethnographic work. While I could interact directly with the technicians at the operations center, much of their work does not happen locally but is distributed across a wide geographic area and involves various human and non-human agencies. As I could not possibly be physically present in several geographic locations simultaneously, I had to rely on co-presence "as an interactive accomplishment by participants and ethnographers alike" (Beaulieu, 2010, p. 457). What this meant was that I had to rely on listening to phone conversations in lieu of direct interactions with the field technicians when they were performing their work; infer remote events from the information visible on the information systems in lieu of observing the actual (physical) changes; and co-create and image together with the technicians the events that took place in distance in lieu of actually seeing them. In other words, the technologies that were focal to my observational efforts were also co-constitutive of the reality in which I performed my work. Thus, the mediation became a feature of the ethnographic research rather than a barrier for it.

I noted down my observations as field notes but also sought to store the events and experiences in my mind as "head notes" (Schultze, 2000). For the written notes, I adopted a template from Schultze (2000) that I followed rather laxly. The note taking was influenced by theoretical interests (Emerson, Fretz & Shaw, 2001) such that I sought to be conscious of the material foundations on which their actions build. That is, in lieu of focusing merely on the discursive aspects, I sought to note down the material foundations on which their actions relied but also to comprehend the material changes their actions implied. By doing so, I was able to observe and infer the agency of the "things" and technologies and not merely the ways in which those technologies become animated through discourse (Cecez-Kecmanovic et al., 2014). While doing so, I was able to note down the performativity rather than representations of their work. That is, to make notes of how their work becomes *performed* (as sociomaterial practices) rather than how their work *is*.

The notes varied between different moments, as some moments are more conducive to note-taking than others. As such, the notes formed a personal account of the events, actors, and actions that would likely be meaningless (and due to my handwriting, probably unreadable) to others (Jarzabowski et al., 2014). Further, as a non-native English speaker, I often found it easier to write notes down quickly in Finnish or in a mixture of English and Finnish, especially, when I did not know the English words (see "Appendix A: Illustrating empirical material").

The field notes form a "jumble of text that seeks to capture the researcher's [my] experience in the field, and to provide a point of reference for accessing that experience again later" (Jarzabowski et al., 2014, p. 277). Later, either during the same day or within the next few days, I sought to elaborate the field notes and create vignettes of some of the events that seemed important. What resulted, was a corpus of field notes that "contains bits and pieces of incidents, beginnings and ends of narratives, accounts of chance meetings and rare occurrences, and details of a wide range of unconnected matters" (Emerson et al., 2010, p. 353).

During the participant observation period, I also read documentation about the company (such as internal newsletters and confidential business continuity plans), about power distribution technologies and techniques, and about the historical development of power grids in Finland and abroad (e.g., Hughes, 1993). These readings were mandatory for developing an understanding, as I have no formal education in high-voltage power distribution, and thus, the culture I confronted was, despite its geographic location and embeddedness in familiar societal culture, very different. That is, I encountered the infrastructure "as a target object to be learned about" (Star & Ruhleder, 1996, p. 113). While the reading provided some basis to develop an understanding of the technicians' work and practices, they merely formed the initial steps, as I still had to come to grips with the local jargon the technicians intensively used. In addition, to aid my learning, the helpful technicians toured me around the physical and messy materials of the power grid through which the electricity flows in high voltage.

I ended the participant observation period in June 2015, when I felt I had acquired sufficient understanding of their work, and many of the events I observed seemed to start repeating themselves. Even before the end of the study, I had heard a couple of times, and from a couple of different technicians, that I could (soon) start working as one of them. While this was certainly exaggeration, and a compliment, I thought I had learned *enough* of the work they do. In addition, the head of the operations also inquired a bit before my planned exit whether I would soon be finished with my study, as summer employees/trainees were about to start and would require the technicians' attention and time. In addition, to my slight surprise, the initial curiosity and openness I had experienced from the technicians at the beginning of my empirical inquiry seemed to now give way to recalcitrance and suspicions. I felt that in the eyes of the technicians I was gradually transforming from the role of researcher to the role of management's henchman. These factors contributed to ending the participant observation period.

3.3.2 Empirical analysis

While ethnography does not need to be theory-driven, or even theory-informed, I have valued the theoretical interpretation of the phenomenon. van Maanen (2011a) refers to these types of ethnographies as "realist tales" in that they explain the phenomenon through a specific theoretical lens. Such accounts are especially valued by the prestigious journals of our field (Rowe, 2012) and provide more generalizable findings (e.g., from descriptions to theory types of generalizations (Lee & Baskerville, 2003). I already had some familiarity with sociomateriality before the fieldwork, but it was not until the fieldwork that I came to realize the suitability of agential realism for explaining what I was observing. More specifically, the agential realist conception of agency emerged as a useful lens through which to make sense of the reciprocity between action and matter in a smart infrastructure context, which I later coined as *infra-acting*. While the choice of theory was certainly informed by the fieldwork, I tend to agree with the assessment that the "theory choices (the rabbits we pull out of our hats) rest as much on taste as on fit" (van Maanen, 2011b, p. 223) (see also Walsham (2006) for similar arguments).

Analyzing the empirical material had already begun during the fieldwork, as I sought to categorize my experiences and notes. These "processes [of analyzing and theorizing] were not separate from the fieldwork as they continually fed back and impacted on the fieldwork" (Cecez-Kecmanovic et al., 2014, p. 571). During this, I followed standard practices of qualitative analysis when going from first order constructs to theoretical descriptions (Miles & Huberman, 1994). Empirical analysis took place even at the most surprising moments and places, such as when I was commuting or doing various leisure activities. However, as Russell (1945) elaborates, these moments of creativity can be misleading:

> William James described a man who got the experience [of sudden insight] from laughing-gas; whenever he was under its influence, he knew the secret of the universe, but when he came to, he had forgotten it. At last, with immense effort, he wrote down the secret before the vision had faded. When completely recovered, he rushed to see what he had written. It was: "A smell of petroleum prevails throughout". What seems like sudden insight may be misleading, and must be tested soberly when the divine intoxication has passed. (p. 124)

Thus, I noted down the ideas that emerged during these sudden insights and used them later to more systematically organize the emergent ideas and relations. The emerging ideas had to then be compared more carefully against my field notes and head notes. Figure 3 illustrates one part of the analysis that I used to organize my research.

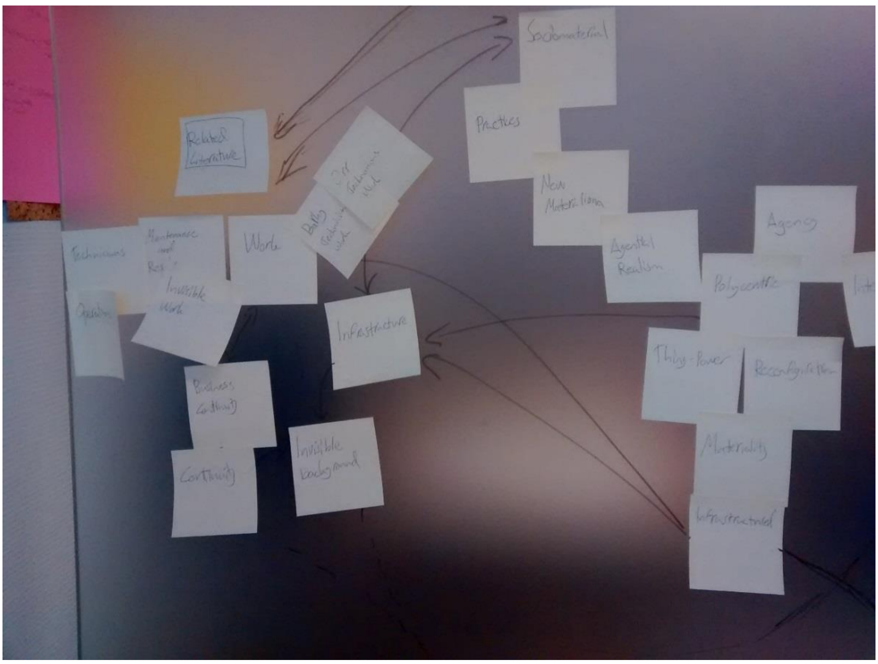

Figure 3. Conceptual mapping with Post-it® notes

The formal part of the technicians' work seemed to evolve around what I referred to as maintenance and repair work (c.f., Graham & Thrift (2007)). That is, the grid seemed to be constantly torn apart, cleaned, greased, and put back together through ongoing maintenance activities aimed at ensuring the smooth operation of the grid. When abrupt moments of breakdowns and incidents arose, the grid was fixed and mended to restore the flow of electricity through joint repair activities. According to my observations, these activities seemed to become established through four types of recurrent and joint actions:

Knowing—the activities through which the current state and operations of the grid become known.

Diagnosing—the activities through which cause-effect chains become surmised to extrapolate the effects of actions or explain past events.

Harmonizing—the activities through which the amalgam of heterogeneous agencies constituting the infrastructure become aligned toward a mutual end.

Vagaries—activities that engender the erratic manifestation of effects.

These categories of actions are more or less analytical. If one thinks of the flow and flux of everyday life, the performances through which everyday life is brought to bear, it is not formed of isolated and clearly demarcated containers that merely await their discovery. That is, when does one action end and another begin? The categories of actions are thus not representations of certain *a priori* entities but rather categories I have been a part of enacting that provide ways of organizing that flow of actions into categories.

The unfolding of these recurrent actions seemed to be entangled with the materiality of the grid. By reading agential realism and the empirical material through each other, I surfaced four mechanisms that explained why the actions unfolded as they did:

Historicity and sedimentation of practices (historicity, in short)—actions become performed in relation to the material history of the infrastructure.

Polycentric and agentic constitution (polycentric and agentic, in short)—actions are not performed in isolation but become enacted in relation to the whole material and agentic constitution.

Dynamic and invisible agencies (dynamic and invisible, in short)—actions become differently enacted in relation to the dynamically changing constitution of the infrastructure.

Precarious and discontinuous material foundations (discontinuous, in short)—actions are founded on unreliable and unpredictable material foundations.

These mechanisms provided a way to understand the boundary conditions within which actions unfold and agency operates. In agential realist terms, they form the space of possibilities for reconfigurations. It is this historical, polycentric, dynamic, and precarious space of agency, which I conceptualized as *infra-acting*, that is a key aspect of the performative view of infrastructure continuity as I have described it here. While it is possible to analytically separate the precarious material foundations from the corollary manifestation of actions as vagaries, in practice they are inseparable. For instance, a failed attempt to control a remote switch manifests as failed action and is corollary to the unpredictable material foundations. As such, when describing and illustrating these aspects, I will discuss them as one (see

"4.3: Performing infrastructure continuity: knowing, diagnosing, and harmonizing"). Appendix A: Illustrating empirical material provides excerpts of the field notes to illustrate some of the mechanism–action duplexes (e.g., relation between knowing and historicity).

After uncovering these categories, I constructed examples from the empirical material to illustrate the entanglement of the mechanisms and the recurrent actions. These examples are *a posterior* constructions of events and actions that might have taken place on different days (c.f., Orr, 1996; van Maanen, 2011a). They rest as much on the field notes as they rest on the head notes and provide as truthful an account of how things work at the operations center as possible.

4 EMPIRICAL SITE: SMARTGRID CO.

The empirical material of this dissertation is based on an ethnographic study of technicians working at a power distribution company's operations center. In this chapter, I elaborate the empirical details by first describing the historical, social, and material context of the study (c.f., Klein & Myers, 1999). Second, I will describe the work of these technicians in a contemporary smart infrastructure setting and describe some of the reorganizing of their work that has taken place along with the digital transformation of the grid. Last, I will provide empirical illustrations of the work together with the analytical categories of infra-acting. In other words, the chapter provides details on what work the technicians do, how they perform it, and how this performance contributes to infrastructure continuity. The discussion is based on articles #5 and #6 but is more elaborate than what has been possible within the space constrains of the conference articles. As such, these details and the more extensive discussion complements the descriptions in the articles.

4.1 The historical, the social, and the material context

SmartGrid Co. (a pseudonym) is one of the oldest power distribution companies in Finland, whose roots date back to 1898. An over 100-meter-long red-tiled chimney decorated with a large glowing bright red Fibonacci numbers sign—an artwork by Mario Merz—is a visible mark of the company's physical location and can be seen even from a great distance. The chimney has become a well-recognized landmark of the city and a distinctive mark on the city's landscape. New buildings have been gradually built around the old granite building where electricity used to be produced with steam turbines. While electricity is no longer produced here, the history is still very much visible and present, as the steam turbines have been turned in to props to showcase this extensive and colorful history (see Figure 4).

Figure 4. Technicians around an old generator from ca. the 1930s

As is typical for Finnish power distribution companies, the company is owned by the city in which it operates. SmartGrid Co., when counted by the number of subscribers, is one of the largest of the country’s 80 power distribution companies. Nevertheless, in a small country with less than six million inhabitants, all the companies, with the exception of a few, are rather compact and small. While SmartGrid Co. sells electricity to all parts of Finland, they manage the distribution only within the area of one city that extends over the area of around 250 km^2. This area covers the city area, plains, and forests and also islands of which some are only accessible by boat. A small group of around 20 employees is responsible for the smooth daily operations of the grid. This group consists of technicians that operate the grid but also niche experts that have specialized in certain areas, such as substations, relays, or information systems. Most of the technicians have worked for the company for a long time. Despite the constant layouts and reorganization of work, which seems to take place in the broader society, SmartGrid Co. is still a company where it is possible to have a lifelong career. Many of the employees started working here directly after graduating (often as engineers) and will continue until retirement.

During the company’s history, the public expectations for the delivery of continuous flows of electricity has significantly increased. The infrastructure that used to merely power the lightbulbs in factories nowadays powers all aspects of society. The grid has become a true lifeblood of the city. For the technicians, this increased demand is very palpable. Even short outages do not go unnoticed by the customers, and any larger outages easily exceed the threshold of being recognized by the national news and even become prime time top news. As the technicians sarcastically explained, the customers have become so accustomed to constant flows of electricity that their reaction times of contacting the customer service in an event of failure seem to surpass even the grid's high-tech automatic fault recognition systems.

While the grid has been renewed over time through a series of maintenance efforts, the planning horizon for the grid is quite different from the planning horizon of most stock exchange companies. "Our quarter is 25 years, not three months," one of the very experienced technicians explained. In practice, this means that when components of the grid are renewed, they are expected to last for the next 25 years. Reflecting this, the grid still consists of cables and switches that date decades back. Indeed, some cables dug under the city streets and that are still in use date back to the 1950s. This long history is also carried in the materiality of the grid (and in its topology), which reflects economic rationales and decisions made decades ago. The older parts of the grid have been built using air wires hung onto utility poles, whereas most of the newer parts are built using isolated cables that are dug underground. Such cables (and especially their installation) used to be significantly more expensive than building the grid with air wires. As the country was being "electrified," and the electricity did not have as stringent service level requirements as nowadays, the cheaper option was often the preferred option. Since the wires were relatively expensive, the shortest paths from A to B were often also preferred rather than the most reliable paths. For instance, air wires that go through forests are exposed to falling trees and tree branches that are a common cause of outages. As such, these past decisions are still carried to the present in the materiality of the grid, which creates inertia and friction to meet the shifting organizational goals engendered by the exogenous demands for uninterrupted flows of electricity.

The automation and digitalization of the grid has evolved gradually. Before 1999, the grid was managed using an in-house developed manual "information system" (see Figure 5). On this manual system, the topological map of the grid was represented as a wireframe diagram drawn on a wooden chipboard. The green pins are small lightbulbs that lit up when one of the yellow buttons was pressed to indicate the flow of electricity in the grid. By pulling away some of the green pins, the technicians could diagnose what consequences a certain failure had on the overall flows of electricity, and thus, used it to aid in planning maintenance work and troubleshooting failures.

Figure 5. Old manual "information system"

Nowadays, similar functionalities have been implemented as information systems. Two systems form the core of the information systems the technicians use daily. An information system known as the Distribution Management System (DMS) combines the functionalities of workflow management, the geographic information system, and health monitoring. Installed in 2005, the DMS is the modern equivalent of the manual system, as it provides the technicians the topological configuration of the grid overlaid on a map along with a coloring scheme to indicate how the electricity flows in the grid. Changes in the flows of electricity in the grid change the coloring of the lines seen on the DMS, and each color signals a different circuit. Using this system, the technicians at the operations center are also able to see the whereabouts of the field technicians who work on the grid (or more precisely, the location of the cars they use).

The homogeneity, unity, and uniformity depicted by the DMS is, however, deceiving. A different kind of reality confronts the field technicians on site. A heterogeneous amalgam of mechanical devices and digital technologies installed over the course of several decades form the technological and material base of the grid. Warehouse-sized equipment is represented by merely a small square on the DMS and is operated without effort by a simple click of a mouse. The click has, however, very concrete material effects. One of the technicians explained operating a high voltage switch: "The noise there [at the substation] is really loud. It's like shooting with a cannon!" However, another information system is needed to control these substations: the Supervisory Control and Data Acquisition System (SCADA).

SCADA is used to monitor and control the substations from where the electricity is fed to different circuits. The current SCADA was installed in 1999 and is still running on a Unix operating system that is viewed by the responsible niche expert to far exceed other operating systems in terms of reliability. The graphical interface of the system says a lot about its purpose and context of use. While it represents the latest generation of this type of system, aesthetically the system is very minimalistic. With simple wireframe diagrams and standardized symbols on a gray background, the system lacks any of the graphical candy we have gotten used to in contemporary IS. It is clearly an industrial IS that is built for its purpose, not for entertainment. The diagnostics information, such as metrics on the current load, the state of various switches, and the configuration of the substations, are important materials for the technicians when evaluating the possible consequences of their actions taken to operate the grid. But in addition to the metrics, the system provides alerting capabilities when things go wrong. Each type of alert has a different type of sound that can be used to infer the severity of the alert. The soundscape here is hectic and even occasionally chaotic.

The technicians work in a shared and open space. Glass doors and electronic access control isolate the space that the technicians populate 24/7 from the rest of the building. The raised floor of the operations center makes footsteps sound peculiar and recognizable. The hollow sound is very familiar to anyone who has visited contemporary hosting facilities and the like. Boomerang-shaped tables with rows of monitors, keyboards, Internet Protocol-based phones, office chairs, and similar office appurtenances characterize the room, and a large screen in front of the room gives the room the typical operations center characteristics. This room, dedicated solely for grid operations, forms an important space for discussing the organization of the work and other issues pertaining to work, but it also provides an important recreational space.

Each morning at around 7:00, just before the field technicians head out to the field, they arrive at the operations center to go through their daily work tasks. They are easily distinguishable from the technicians who spent their days at the operations center. While the technicians at the operations center wear their personal clothes and thus resemble any other office workers, the field technicians are recognizable from their military-style black boots with protective steel caps, bright orange overalls knit from some thick plastic-like yarn to protect the technicians against fire, and white plastic helmets—all of which are mandatory equipment for anyone in direct physical contact with the components of the grid. During the daytime, this same space provides a discussion forum for addressing any emerging issues between the technicians, but it also provides a recreational space in which personal matters and issues are discussed. Further, the operations center is a space where stories from the field are being told and spread. These stories convey the vitality and challenges of working with the tangible, rigid, resisting, concrete, and heavy materials of the "real" world. They educate and train, but also entertain. The vicarious sights and everyday experiences of the field technicians become stories of careless and intoxicated vagabonds who under unclear circumstances, and in the middle of the night, burned down their house; of a drunken driver whose unfortunate and illegal ride ended in a collision with a utility pole; of an exploded and demolished power distribution facility that was torn apart by a sudden unleash of high voltage electricity; and of a senior citizen who climbed into the bucket of his front loader to lift himself up using strings attached to the control levers of the vehicle in order to cut tree branches, only to accidentally cut the power wire feeding electricity to his house. The operations center is thus the heart of the company, at least for the technical staff.

4.2 Technicians' work in contemporary smart grid

Situated in front of the boomerang-shaped desks and the nexus of information systems, communications technologies, and other appurtenances, the technicians perform their daily work (see Figure 6).

Figure 6. Technician at work

The communications technologies form an important part of the work by connecting the technicians with the field technicians, customers, and partner companies. A dedicated communications channel for the critical infrastructure operators provides the default way of communicating with the field technicians ("VIRVE" in Figure 6). Brief and formal communication protocol is applied when using this channel. It is meant for communications required for operating the grid, and not for chatting. However, often the need for more elaborate discussions arises, and another communication channel becomes established on the technicians' IP phone-based headsets. This prompt switching between monitors, keyboards and mice, taking notes with pen, discussing with (local) fellow technicians, and switching between the communications channels is like juggling several balls at the same time and hoping that none will drop.

Structured, routine-like maintenance work paces the technicians' days. Equipment needs to be tested, switches greased, premises cleaned, cables renewed, and so forth. These maintenance tasks are preemptive measures that form the foundations for the continuous flows of electricity. The maintenance efforts are structured by standard operations procedures (SOPs) that document step-by-step instructions for performing any planned maintenance work. The documented instructions are brief statements that document the location where effects should take place together with the operation to be performed. These steps cut complex procedures into simple and manageable operations, such as changing the state of a single switch or placing a "Men at work" sign. Despite the fact that each and every SOP is always reviewed and simulated before actually performing that work, occasionally the operations cannot be performed as documented. The SOP might simply contain errors (such as incorrect location) or it might require reconsideration in some more complex way. Thus, the actions that constitute the routines need to be jointly accomplished and re-accomplished for the routines to become established.

Occasionally, abrupt and unexpected events disrupt the technicians' maintenance tasks as the SCADA makes a sound as an indication of a failure. The occasion gives rise to new concerns. What has happened? Where did it happen? And why did it happen? The grid is distributed and spread across a broad geographic space, but it forms a linchpin that connects agencies and spaces/places. The significance of distance between the events and the effects in geographic terms lose their significance over concerns of connectivity and (organizational/material) boundaries between these spaces and places. The events that take place at a distance have very palpable and concrete local effects at the operations center. At these moments, the technicians face the challenge of surmising an explanation with the available materials. The initial status of knowing something has happened becomes gradually and iteratively refined and reconsidered.

Repairing is a joint activity that rests on the information systems (plus other technologies), other technicians, and customers, but also on electricity itself. That is, the technicians' possibilities for actions needed to repair the outage is dependent on mobilizing a host of other agencies. For instance, when the outage is related to an air wire, the first action is to reconnect electricity to the faulty line from SCADA. Reconnecting electricity creates new materials for the technicians to work with, even if reconnecting fails to restore the electricity. The enormous force that high voltage electricity contains may combust or even explode any blockages on its way. Thus, tree branches or unfortunate animals or birds that have become unexpectedly (and most likely unwantedly) appended to the material constitution of the grid are forcefully detached. When the attempt fails, information on the residual-current that the failed attempt creates may help to further pinpoint the exact location of the incident that is crucial for the technicians to instruct the field technicians to find the right location promptly. However, such attempts also have other material effects. Despite the fact that the protective mechanisms of the grid automatically disconnect the current in virtually no time (i.e., in scales of milliseconds), a short-circuit on the power line creates significant heat. Attempting to reconnect electricity (too soon) after a failed attempt can cause severe damage to the equipment, as the metal components can literally melt. Thus, the actions need to be aligned with and accommodate the aggregated history of past (material) effects.

When the topological configuration of the grid allows, the electricity can be routed to an alternative path. As such, the technicians' possibilities for repair actions become entangled with the economic rationales of the market economy embodied in its matter. Areas considered "too remote" and "not sufficiently" populated are economically less interesting and, therefore, often lack alternative paths. The technicians' possibilities for repair actions are thus not solely relational to any specific trait traceable to the technicians per se but attributable to the situation-specific configuration of the infrastructure—to the human and non-human agencies that constitute that situation and the infrastructure.

Occasionally, the performance of work leads to unexpected results, as the grid does not materialize the expected effects. The grid seems to always embody a degree of uncertainty such that any action is always founded on shaky grounds. That is, it seems impossible to know the outcome of any particular instance of action before its enactment. Often these surface as the inability to operate some remote control. In these moments, the geographic space between here and there becomes a very concrete barrier to action, but also time becomes an issue. The place/space within the reach of a mouse becomes at that very moment frustratingly distant, as field technicians have to drive to the physical location and enact the changes manually (and hopefully also fix the remote control). For instance, accomplishing a maintenance task becomes complicated when a remote control at a distance fails to perform due to the failure of a signal regeneration device between the operations center and the remote control that has run out of electricity. While in this example the failure is traced to a faulty regeneration device, occasionally no immediate and visible reason for such failures are found, and the event becomes yet another representation of the mysterious ways in which the grid works.

In summary, what the above description highlights is that the materiality of the grid shapes the unfolding actions that take place as part of the infrastructure. These actions manifest in relation to the material history of the grid and to the distributed, agentic, and dynamic (i.e., changing/shifting) constitution of the grid. These mechanisms are also discussed in articles #5 and #6.

Despite the fact that the maintenance and repair work are aimed largely toward different ends, they become performed through a set of recurrent and jointly (re)accomplished actions. This repertoire of actions consists of knowing, diagnosing, and harmonizing.

4.3 Performing infrastructure continuity: knowing, diagnosing, and harmonizing

The formal part of technicians' work is wholly distributed and sociomaterial (i.e., entangled with materiality). Performing the work would not be possible without the sensors, fibers, copper cables, wireless signals, and information systems that are jointly responsible for creating information for the technicians on the current configuration of the grid, on its load, on the flows of electricity, and so forth. As Jonsson et al. (2009) and Østerlie et al. (2014) have also shown, the information constitutes the new materials the contemporary technicians' work with.

In Table 2, I provide an overview of the reciprocity between infrastructures and action. For the analytical categories of actions (knowing, diagnosing, and harmonizing, and vagaries) and the infra-acting mechanisms (historicity, polycentric and agentic, dynamic and invisible, and discontinuity) see 3.3.2 Empirical analysis. As discussed in the aforementioned section, the table combines the vagaries and the discontinuity due to their interrelated nature. Next, I will elaborate how the technicians' performance of actions contributes to infrastructure continuity.

Table 2. Performance of actions in a smart infrastructure context

Knowing	*Diagnosing*	*Harmonizing*
	Historicity	
Knowing is relational to the historical development and technological constitution of the grid. For instance, surmising an explanation for outage builds on knowing the historical development	Diagnosing is to uncover the trajectories of past actions and events to extrapolate future actions and events. For instance, uncovering the past changes in the configuration of the grid to determine the	Harmonizing builds on the historical materialization of the grid for possibilities to establish coordination. For instance, establishing coordination with switches that have not been installed with

of the grid and past incidents such as incidents typical for certain places.	feasibility and possibility of further actions and their effects, e.g., actions might be diagnosed as unfeasible due to existing maintenance work in the grid.	remote control technologies requires field technicians' physical presence (plus communications channel, plus plenty of other appurtenances).
Polycentric and agentic		
Knowing happens as a joint and distributed accomplishment by the human/non-human agencies that constitute the grid in any given moment. For instance, knowing the current load of the grid is founded on the amalgam of technologies that measure the volts, the amperes, and other metrics from the flow of electricity.	Diagnosing builds on various agencies that jointly define how the infrastructure becomes visible. For instance, when electricity is connected back to a faulty line, the electricity becomes a part of the joint efforts to make visible the "thing" that creates incidents.	Harmonizing is about establishing (and preserving) the alignment of distributed and heterogeneous human and non-human agencies toward a mutual end (i.e., to distribute continuous flows of electricity). For instance, restoring flows of electricity after an incident consists of controlling remote controls, utilizing sensors, rerouting electricity, instructing field technicians, (physically) locating outage, and so forth such that the flows of electricity become restored.
Dynamic and invisible		
Knowing is dynamic such that the technicians' knowing varies from situation to situation. For instance, an unexpected call from a customer who has witnessed an explosion creates new material for the technicians to work with.	Diagnosing is to render the dynamic constitution of the infrastructure visible when estimating the effects of action and to surmise an explanation for an outage. For instance, reconnecting electricity to a faulty air wire utilizes electricity to create information to further surmise an explanation for an outage (e.g., if the attempt fails, it is likely to be a fallen tree, especially if it is windy).	Harmonizing requires establishing coordination with agencies that often change (i.e., are dynamic) and that are often not known before they have an effect (i.e., they are invisible). For instance, a critter that has come in contact or a customer who calls as an eyewitness becomes a part of the overall efforts to harmonize agencies to produce flows of electricity.
Discontinuous (Vagaries)		

Knowing about the grid is erroneous when the information is false. For instance, an IS (DMS, SCADA) produces information that is disconnected from the actual configuration of the grid (e.g., a switch status is shown incorrectly).	Diagnosing failures occurs when a (jointly) surmised explanation for an outage turns out inaccurate or incorrect or when a planned change turns out infeasible. For instance, when an expected location for the cause of an outage turns out to be different than the result of the diagnosis (e.g., IS fails to correctly locate the incident).	Harmonizing is erratic when establishing the coordination of the human/non-human agencies fails. For instance, a distant remote control fails to execute, as the signal regeneration equipment is without electricity and has drained battery backup due to (unrelated) power outage.

While some of the *maintenance* work is done to enable others to perform their work (e.g., that construction workers can work in close proximity to the power lines), much of it is to maintain equipment against wear and tear—to prolong or to even avert the otherwise inevitable decay. These efforts form an important part of the dynamics through which the power infrastructure evolves, but performing this kind of work is also key for infrastructure continuity. Without the efforts through which the equipment becomes maintained and renewed, and new technologies become installed, the infrastructure would gradually cease to function, fade into nonexistence, and become merely a vestige of the infrastructure it used to be. The work is, however, not merely dependent on the technicians but builds on jointly accomplished actions. The following vignette of typical maintenance work serves to illustrate these actions (all names are pseudonyms):

> *Mark, as usual, arrives at work around 6:50, just early enough so that Peter, who has worked in the night shift, still has enough time to give him a short briefing of the events that took place during the night shift. It's been a quiet night as usual, so they focus on going through the maintenance work that is planned for today. Peter has verified the plans during his shift, and the plans [SOPs] are ready to be executed. Promptly after, several field technicians, already wearing their bright overalls, arrive at the operations center to go through today's work and after the briefing head out to the field each with their own VIRVE phone. Mark stays at the operations center. The plans are laid in front of him, and he now needs to wait for Steve, a field technician, and his work pair to arrive at their destination. For Mark, the destination is visible simply as one of the several small interconnected squares overlaid on a map of the area on the DMS. As soon as Steve has arrived at the location, he, following the communications protocol, dispatches briefly and formally through the VIRVE: "operations center, Steve." Mark replies, "operations center, listening." Steve informs they are ready. Mark, following the SOP, instructs "open Main Street toward Eastern*

Street" to have Mark operate a disconnector with a long nonconductive tool that disconnects electricity from the switch and from the cable attached to it going toward Eastern Street. Soon after, the phone rings. It's Steve. Steve has switched the communication channel to speak more freely with Mark than is possible through the VIRVE. Steve expresses his worries, as it has turned out the equipment is several decades old and not in the best shape. When the disconnector is operated, a strong compressed spring launches and quickly separates two metal blades. If the blades do not open quickly and become stuck, in the worst case, the high current electricity can "jump" to the field technician and cause severe injury. He is not willing to take this risk. Mark turns to the DMS and analyzes the situation. They come up with an alternative course of action. It seems that a switch upstream from Steve can be operated remotely. Mark has to just ensure that operating this switch does not cause power outages to any of their customers. He then turns to the SCADA to operate the switch, and after few mouse clicks informs Steve that the switch is now "cold" [without current]. The remote control allowed Mark to perform the operation in virtually no time, whereas it would've taken close to half an hour for Steve to drive back and forth. Steve is now able to operate the switch safely without having to worry about the electricity "jumping" at him.

From the vignette, it is possible to see how the possibilities for action become jointly created and attributed to the amalgam of Mark, Steve, DMS, SCADA, and the remote control. Mark's initial *knowing* of the location changes as Steve arrives at remote location and gives Mark additional material to work with. As they face the issue of operating the old switch and the constraining effects of the historicity of the grid, Mark promptly engages in *diagnosing* new opportunities. As he entangles with the DMS and SCADA to start diagnosing the flows of electricity and the technological configuration of the grid, new possibilities for acting become enacted. To perform the necessary actions required for the maintenance task, Mark *harmonizes* the human and non-human agencies—SCADA, the remote control, and Steve—to accomplish a coordinated action.

The constant and ongoing cycles of maintenance are abruptly disrupted by sudden, and often unexpected, needs for *repair*. As I came to learn, discussions with any of the technicians will most likely point out three common reasons for repair: (1) heavy winds, (2) pesky critters, and (3) careless excavators. The following vignette provides an illustration of such repair work:

The day has turned to afternoon and Mark has just returned from his lunch break. The morning's weather forecast predicted heavy winds for the afternoon. The first signs are already starting to appear. On the large screen in front of the operations center, a digital anemometer, provided as a service by the Finnish meteorological institute, shows wind-speeds already close to 25m/s. The measuring point that can be freely chosen amongst several available options is set to show the wind-speed at a small rocky island just outside the city. Due to its open location at sea, the wind blows *often heavier there than on the shore. However, it gives Mark a good heads-up and early warning cues that the wind might be approaching the shore soon. He turns to one of the monitors and browses the homepage of one of the neighboring power distribution companies. Experience has shown that often the wind blows so that the neighboring company will experience the first outages before the wind reaches here. Also, this time, the publicly available outage information service shows red dots indicating power outages. Mark mumbles, "so…here we go…," as promptly after viewing the outage service the SCADA turns boisterous. A high-pitch, bell-like sound is followed by several other sounds of varying pitch and frequency. While the sounds indicate the severity, they give no information about the location or about the incident itself. Mark turns to SCADA to review the new alerts that have arrived to start surmising explanations as to what, where, and why. The alerts show information from the view of the component that has sent the alert. It indicates the location of this component and shows Mark that the protective mechanism has activated and the disconnector has automatically launched. What it also shows are metrics about the electrical current that launched the automatic protection. DMS uses this information to automatically calculate the estimated location of the incident—but not this time. Mark notices that the icon indicating outage is placed almost exactly where the component itself is located. He expects this is not the actual place of the incident. Thus, he notes down the metrics from the alert and calculates the approximate distance of the incident from the switch. While doing so, he's already dispatching field technicians to start driving toward the location. After a protocol-compliant handshake, Mark communicates, "A disconnector launched. It's probably a tree. Go and check the line between Upper Street and Backhill." Mark knows it'll take close to half an hour for the field technicians to drive there. And after driving there, they have to start following on foot the wire pathways that go through a forest to find the exact incident location. Mark estimates the situation further. Unfortunately, the area does not have alternative paths to route the electricity. However, if Mark's calculation is correct, by utilizing remote control, he can separate the faulty part with a disconnector and feed electricity from another substation until this disconnector. By doing so, it would be possible to restore electricity to some of the customers before the field technicians are able to find the incident location and remove the obstacle from the wire. In just a matter of seconds, Mark controls the grid, and, as a result, the electricity in the grid starts flowing toward the disconnector he just operated. The white line on DMS (indicating "cold" lines), changes color to indicate the electrical circuit to which the wire now belongs. The change was successful, and now Mark has to wait for the field technicians to arrive at their destination.*

The sudden, yet expected, outage gives rise to new concerns but also new conceptions of time (and space). The material changes at a distance have very concrete local effects that transform the pace of the technicians' work. The space-in-between becomes a very concrete and palpable barrier to the technicians' possibilities to perform actions. The incident at a distance becomes initially known only through the materials the IS creates. The anemometer, the neighboring company, the location of the event, the past vicarious and direct experiences of the technician, and the alert all jointly create the configuration for possibilities of *knowing*, of surmising an explanation in order to be able to know but also to act. The metrics and information the alert contains become "possibly a tree," thanks only to this mélange of human/non-human agencies. The topological configuration formed by the material connections between places reflects the historical materialization of the grid and limits the technicians' options. By *diagnosing* the configuration of the grid with the IS, Mark creates new possibilities for acting. That is, coming up with the new possibilities rests on the IS. The remote control becomes crucial for the repair efforts, as it enables limiting the impact of the outage in virtually no time; the remote technology performs a different space/time conception and enacts new realities for Mark to act. While the *harmonizing* failed initially as the location of the incident was misplaced on the DMS, the harmonizing action becomes successful as Mark operates the remote control, and electricity starts flowing again to (some of) the failed parts. As alternative routes lack, Mark can then only wait as the field technicians are able to remove the tree creating a rigid and tangible barrier to the flow of electricity.

To summarize, when infrastructure continuity is analyzed in practice, it becomes visible that the patterns of stability and permanence the grid depicts are jointly formed through constant and ongoing actions. That is, infrastructure continuity surfaces as an accomplishment attributable to the human/non-human configuration. How these patterns materialize, that is, how the actions become performed are corollary to the materiality of the infrastructure (i.e., to the four infra-acting mechanisms).

5 SUMMARY OF THE ARTICLES

The foundation of this dissertation is composed of six articles. The articles partly overlap and also depict a diachronic development of the ideas and focus of the dissertation. Indeed, the diachronic development can be attributed to the qualitative and ethnographic research approach that this dissertation work has followed; I have maintained openness and sought to value surprises and breakdowns as opportunities to reconsider my assumptions and preconceptions. Next, I will summarize the six articles. The original published articles are included in Appendix B: Selected publications.

5.1 Article #1: Interdisciplinary review of business continuity from an information systems perspective

In this review article, I sought to understand how organizations can prepare for IS incidents by building on the prior multidisciplinary research on business continuity. For reasons of feasibility, I delimited the study to those articles that connect their research to "business continuity" explicitly and to those that had been published after 2000. I uncovered 83 articles dealing with socio-technical issues that are relevant for IS researchers. I refer to this body of knowledge as "IS continuity," which is a subset of the broader business continuity literature that deals with all sorts of business continuity issues. The review uncovered, perhaps surprisingly, that there is a short shrift of studies in the key journals of our discipline. With few exceptions, most of the publications in IS have appeared in niche journals that focus on information security research or in disciplines other than IS. This is rather surprising, as both practitioners and scholars seem to agree on the importance of such issues for organizations and societies.

Business continuity originates from practitioners (Zsidisin et al., 2005), which can explain why the research has also remained largely instrumental and atheoretical. Disciplinary differences on the importance and role of theory as well as journal preferences has meant that business continuity has remained as a practical domain of inquiry with little to no theoretical development. To mature as an academic domain of inquiry, there is a need to develop the theoretical rigor.

Through hermeneutical analysis of the literature (Boell & Cecez-Kecmanovic, 2014), I came to understand that the literature can be described in terms of categorizing the approaches to three themes:

- Social aspects as IS continuity enabler,
- Technology as IS continuity enabler, and
- Models that improve IS continuity.

Building on the themes, I propose a framework for IS continuity that integrates the themes and identifies their potential interaction. In doing so, the framework underscores the socio-technical nature of business continuity and draws attention to the tight interrelations between the social and the technological aspects in IS continuity. That is, the social aspects of business continuity are tightly anchored to the technological infrastructure of the organization. The framework further separates business continuity into two separate but interrelated phases: (1) the period of "normal" operations and (2) the period of when an incident is active. As such, business continuity is not merely tied to the organizational preparations for incidents but also covers active response and recovery from an organizational incident. I propose several gaps to be studied in future work that focus on the mutual and reciprocal interaction between the social and the technological when preparing for IS incidents but also when responding to and recovering from those.

5.2 Article #2: Extending 'toolbox' of business continuity approaches

Inspired by the literature review (article #1), I sought to extend the existing approaches by conceptually developing ideas from a practice perspective to business continuity. The article provides a discussion on the three main approaches to business continuity to position an emerging perspective I refer to as "practicing continuity" as an alternative way to study and understand business continuity. Practicing continuity extends the prior literature that has recognized the importance of organizational work practices and routines for business continuity. From this perspective, while methodologies and technologies may be used to improve the effectiveness of organizational business continuity, in the end, it is relational to how the humans, the technologies, and the plans come together and become enacted in practice.

Building on sociomaterial practices, I suggest that practices, as amalgams of humans, technologies, and other material artifacts—the building blocks of any work—form a space of possibilities for performing the tasks required to get work done. This space formed by the different "components" (or "agencies" in agential realist terms) also defines whether it is possible to get work done. The challenges posed by incidents then are that they abruptly reconfigure this material constitution of work and, consequently, the space of possibilities. As such, when viewed at a practice level, organizations' business continuity emerges from these practices that take place within the space of possibilities of what outcomes are possible with the available materials. Organizations' business continuity is not thus merely dependent on whether a certain IS is available or dependent on the comprehensiveness of plans when an incident arises but also on whether the work can be performed through alternative means and on who is performing the work.

The article contributes to prior research by arguing that business continuity cannot be the designated property of any individual thing but is always relational to the whole sociomaterial constitution of work. Thus, a useful unit of analysis is a sociomaterial practice rather than any discrete entity alone. In addition, the conceptual analysis suggests that organizational work and practices may self-organize within this space also when confronted by an incident and when employees need to find alternative ways of working.

5.3 Article #3: Sociomateriality and information systems

Since the emergence of sociomateriality in IS research, it has evoked intense debates and has drawn criticism. As a result of these debates, sociomateriality has become an umbrella term that covers a broad range of theoretical and philosophical underpinnings. In this study, I sought to surface differences between the two main approaches to sociomateriality by juxtaposing the underlying philosophical perspectives and the conceptual "tools" that each of the perspectives provides that can be used to make sense of IS phenomena. The study extends earlier discussions and debates on the philosophical foundations and differences between the two main perspectives, highlights areas of IS research to which each of the perspectives seems particularly suitable, and provides a lexicon for the conceptual tools to describe IS phenomena.

A key difference between the perspectives can be traced to their ontological differences. I termed as "radicals" those that build their theorizing on Karen Barad's agential realism and as "conservatives" those that build on Roy Bhaskar's critical realism. While slightly provocative, the naming well captures their ontological positions but also sociomaterial development. The radical perspective departs from the traditional Western thinking that has dominated since Rene Descartes—the ontology of discrete entities and the fixed and given distinction between matter and meaning ("Cartesian dichotomy"). In contrast, the conservative theorizing has sought to preserve the Cartesian dichotomy and fit sociomateriality into this framework of thinking. This is not to indicate that the Cartesian view and critical realism are the same but that they share the commitment to discrete entities from which agential realism radically departs.

The article does not seek to find "better" philosophical perspective to sociomateriality but discusses their differences to identify areas of application. As with any theoretical or philosophical perspective, certain aspects of the world are rendered more salient than others, and, as such, the task is to understand those areas where they are potentially useful. As IS phenomena are so complex and diverse, the areas are not comprehensive but merely illustrative. In the paper, I argue that a key difference for IS scholars is that the radical perspective is particularly well suited to explain broader organizational and societal phenomena and how technologies are implicated in producing those wider phenomena (e.g., infrastructure continuity), whereas the conservative perspective seems more suitable for explaining how different patterns of technology use emerge from episodic and cumulative encounters with a technology.

5.4 Article #4: Sociomaterial ethnography

While some exceptions exists, sociomateriality seems to encourage detailed and in-depth studies on phenomena. Particularly ethnography has been a popular methodological choice for sociomateriality studies in IS. However, in this study, I argue that ethnography has been adopted to sociomaterial studies without explicit consideration of its radical philosophical underpinnings. Especially in IS, ethnography is strongly associated with interpretive research that builds on social constructionist and hermeneutic foundations (Klein & Myers, 1999). In this study, I sought to elaborate the implications of the philosophical foundations of agential realism for ethnographic research.

From Barad's (2007) philosophy, I identified three salient factors that researchers should take into account when conducting sociomaterial ethnographies. First, and most significantly, sociomaterial ethnographies should have sensitivity and pay explicit attention to the material aspects of the phenomenon studied and not only to the social meanings that are customary in interpretive studies. Second, sociomaterial ethnographies need to attend to and describe the changing nature of the phenomenon. That is, they should pay attention to the performative becoming of things and events rather than on the static representation of what is. Last, the researcher should recognize being a *part of* the phenomenon under study rather than within the phenomenon. What I mean by this is that, in contrast to an interpretive stance of mediated access to world (i.e., that any access to the world is mediated through our senses and constructs/preconceptions), agential realism argues that the phenomenon is always relational to its constituent parts. There is no "objective" world "out there" for the researcher to describe, but that researcher is always and already a constitutive part of the phenomenon s/he studies.

Using the identified factors, I analyzed how prior studies comply with the criteria. An analysis of four influential sociomaterial studies indicates that applying these principles is not a straightforward matter, as none of the evaluated studies conforms to all the three aspects.

5.5 Article #5: Analyzing the relationship between workspace and the smart infrastructure reliability and continuity

Technological advancement has meant that technicians' work has become centralized but also simultaneously highly distributed. Activities traditionally conceived of as highly local (such as diagnostics work) can now be performed from even a great distance. Rather self-evidently, for the technicians' possibilities, what technologies and materials they have influences what work they can perform and how they can perform it.

Often, we think of possibilities in terms of utilities and tools that are at our disposal, such as those within an arm's reach that can be directly manipulated and used. This workspace of material things and artifacts is conceived of as local and rather static (despite the fact that the meanings and perceptions of those things and artifacts may vary across time and space). The technological and material constitution of smart infrastructures has meant that the technicians' workspace is not merely that which is local, such as remote control and diagnostics enacting material workspaces and new realities for the technicians' to work in. In smart infrastructures, the workspace is neither local nor static.

To understand these new possibilities, I empirically developed the concept of infra-acting to explain the technicians' possibilities in such technologically enabled environments. When considering what materials the technicians have in order to perform the reliable infrastructure services and to repair the infrastructure when things do not work as expected, the technicians' workspace and the possibilities it provides are not merely relational to the ways in which they make use of and tinker with the local things and artifacts within reach of their arm but relational to those they are connected with and how they are connected. To understand their performance is not so much about understanding their cognition or sense-making capabilities. Instead, it is about understanding the material entanglements, connections, and boundaries through which their possibilities for action become differently established. Thus, while it is certainly true that people vary in their performance on how they make sense of their surroundings and how ingeniously they manipulate and use this environment, it is also true that people vary in their performance depending on how their environment is materially constituted.

5.6 Article #6: Entanglement of infrastructures and action

Like so many other activities in life, technicians' work has become wholly dependent on technological infrastructures. Their work activities rest on the materiality of the technological assemblages and on the materials these assemblages create. In this study, I further developed the concept of infra-acting as a theoretical lens to understand and analyze the entanglement of infrastructures and action. As such, the article builds on and extends article #5.

The empirically observed entanglement inspired me to inquire into and explore forms of agency that take into account the active and agentive role of matter when explaining action. The agential realist conception of agency emerged as a useful foundation for studying and conceptualizing the reciprocity of infrastructures and action. In what I conceptualized as infra-acting, agency is relational to the different configurations of the material constitution of the infrastructure that engenders variance in the manifestation of actions.

Building on agential realism and on empirical analysis, I argue in this study that four (ontological) mechanisms partake in the manifestation of actions. The first relates to the historical development of the infrastructure that embodies the practices of its becoming, or what I, building on Barad, referred to as the sedimentation of practices. This historical development of the grid and practices around it constrain possibilities for action but also enable the development and continuity of practices. The historical development does not have to be historical in the sense that it takes place over years or decades, as sedimentation happens in each reconfiguration. That is, the historical here refers merely to the aggregation of these past reconfigurations, be it actions or other events. The second relates to the polycentric and agentic constitution of infrastructure. Infrastructures are distributed across space and time, yet they are tightly connected. That is, infrastructures form a linchpin that ties various "things" together, but while doing so, they never become unified but merely united. Any action unfolds in relation to this agentic constitution and within the space of possibilities it jointly creates. Third, the infrastructures are not fixed or static but evolving due to their (partly) open nature. However, their constitution is not visible in any totality at any moment but appears in piecemeal fashion through practices through which it is made/becomes visible. Fourth, discontinuity relates to the unpredictable and nondeterministic nature of infrastructures. Infrastructures depict abrupt and unpredictable reconfigurations, which also implies that the outcome of any action cannot be known before the enactment of that action. This discontinuous nature of infrastructures engenders the erratic manifestation of actions where intentions and outcomes misalign. Thus, any action on infrastructure may manifest in unpredictable ways.

These four mechanisms afford a way to understand why certain practices manifest as they do. The mechanisms are an onto-epistemological explanation for why people act with infrastructures as they do. It is important, however, to notice that these are not prescriptive or causal (i.e., predictive) mechanisms but rather explanatory of the space of possible actions. Infra-acting poses that this space of possible actions is not static and that the mechanisms are not unidirectional such that matter would merely form a passive background, a substrate, for action. The actions are also performative of matter and transformative of the mechanisms. What I mean by this is that when performing their work, the technicians also actively shape their own possibilities for action. For instance, when performing an action that engenders material changes (such as the heating of equipment), this action itself is performative of their future possibilities. The limitations imposed by the material changes are thus not merely epistemological (i.e., whether they can comprehend their possibilities and leverage those). These four mechanisms partake in the recurrent performance of actions through which knowing, diagnosing, and harmonizing become jointly, and occasionally erratically, accomplished.

6 FINDINGS AND DISCUSSION

In this dissertation, I have sought to increase understanding on *how continuity becomes performed in a smart infrastructure context*. This purpose was explored through three research questions, which were studied through six research articles. In studying these questions, I have adapted both conceptual and empirical research approaches. The conceptual part builds on a literature review and conceptual argumentation. The empirical part builds on an ethnographic study conducted in a rather traditional industrial setting but in a context where the work performed is entangled with infrastructures. In this chapter, I will first provide a discussion on the findings of the study as they relate to the purpose of this research. Second, I will discuss the contributions constructed through the three research questions. Third, I will discuss the broader implications of the findings in regard to infrastructure continuity and sociomateriality. Fourth, I will discuss the practical implications. Last, I will address some of the quality-related aspects of the findings and the research.

6.1 Summary of the findings

6.1.1 Addressing the research purpose

To summarize, in a broad sense, the findings of this dissertation suggest that when infrastructure continuity is viewed from a performative and sociomaterial perspective, it surfaces as an active and ongoing accomplishment. From this view, rather than resting on any individual—be it human, technology, or a plan—infrastructure continuity rests on recurrent actions. Thus, in contrast to focusing on the *measures that sustain* continuity, it draws attention to the *actions* that contribute to *performing* it. Infrastructure continuity is a temporary and precarious achievement (Graham, 2010) produced through actions. More specifically, to address the purpose of this research (i.e., to explore how business continuity becomes performed in a smart infrastructure context), the findings of this research indicate that infrastructure continuity is a joint (re)accomplishment that becomes established in the amalgam of human/non-human agencies that constitute the infrastructure. That is, infrastructure continuity is the provisional outcome of the performance of a certain sociomaterial configuration. Next, I will elaborate this.

Understanding infrastructure continuity as a sociomaterial performance requires holding actions as always and already entangled with materiality. That is, rather than holding the social and the material as two distinct and separate domains, they are inseparable in action (Orlikowski & Scott, 2008)—they are merely different projections of the entangled whole (Mazmanian et al., 2014) that engender different patterns of actions. These entanglements are performative of possibilities for performing actions. That is, the space of possible actions (Pentland & Singh, 2012) is a specific sociomaterial configuration; any action is always social but also a materially bounded activity. Indeed, this space of action does not need to be perceived. It precedes cognition and experiences—it is onto-epistemological by its nature. Without the material boundaries, performing actions would be merely a matter of intentionality and only limited by creativity and ingenuity. Instead, when we realize that actions are inherently material, we start realizing that the material context matters for performing actions. Situating a technician from a modern high-tech nuclear power plant to a tinkered power grid in a developing country is likely to not in itself suffice to enact any noticeable difference.

Analyzing technicians' maintenance and repair work in a smart infrastructure context revealed some of the internal dynamics of infrastructure continuity. Through constant cycles of maintenance and repair activities, the technicians seemed to contribute significantly to producing the flows of electricity. However, the performance of this work is not separate from the infrastructure but constitutively entangled with its materiality. The technicians are themselves part of the sociomaterial constitution of the infrastructure they maintain. As such, for them the infrastructure is not merely an invisible background for action as it is for the rest of us. Instead, for the technicians, the infrastructure is both a context in which to act but it is also a topic of concern. This sociomaterial constitution both enacts the context in which they work and forms the boundaries in which the work unfolds. It is a context which is partly planned and designed, partly a result of evolutionary development, partly adjusted and tinkered *in situ*, and partly a result of abrupt changes. But it is also a context that is both a technologically created "virtual" world (sensors, remote controls, etc.) and physically bounded by the rigid and messy materials of the "real" world. It is a materially enacted reality with its own specific limitations and rules.

The smart infrastructure shapes the manifestation of actions through four mechanisms[9], which I have collectively called *infra-acting* (see Figure 7). Infra-acting

[9] The "mechanisms" here should not be taken as the critical realist type of mechanisms of the stratum of the real that undergird perception and experience. Rather, the mechanisms here pertain to sociomaterial relations and simply refer to the dynamic space of possibilities that are both epistemic and ontic.

draws attention to the relational and sociomaterial constitution of the infrastructure in shaping actions. That is, the humans (H) and the technologies (T) are always part of a broader social (S) and material (M) (see Figure 7) constitution (see also article #6 for infra-acting). This constitution is also performative of different time/space conceptions. That is, for instance, the remote control technologies re-configure geographic distances as less significant than matters of connectivity for performing actions at distance. The sociomaterial constitution is a plurality that receives its boundaries in relation to the sociomaterial configuration through which it is known. For instance, electricity itself is not "seen" per se but becomes known through the metrics jointly created by the technicians, the sensors, the information systems, and so forth. Consequently, the possibilities for action are not static or enacted once and for all but coagulate only temporarily in the performance of action.

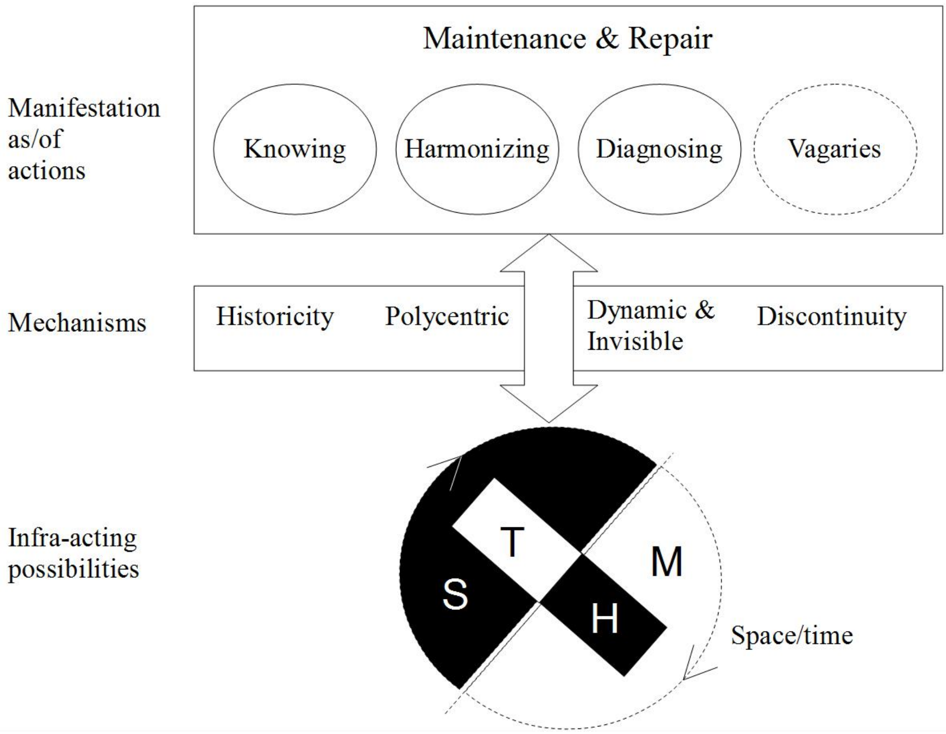

Figure 7. The framework of performing infrastructure continuity

The sociomaterial constitution is performative of the space of possible actions, but also the actions are performative of the sociomaterial constitution. That is, there is a reciprocity between actions and infrastructures—materiality *shapes* the manifestation of actions but *is also shaped* by the actions. For instance, certain actions have concrete material effects as they may heat some of the equipment which then limits the technicians' possibilities. The past actions sediment as part of the history of aggregated actions that condition future possibilities. *(Infra-)Actions are then material enfoldings of the infrastructure*. Thus, to conclude, it is the material constitution of the infrastructure that importantly shapes what work is done and how it is performed.

The actions through which maintenance and repair are performed (see Figure 7) manifest from the material foundations (see "4.3: Performing infrastructure continuity: knowing, diagnosing, and harmonizing" for a more elaborate discussion on these actions). Performing the actions is always a joint accomplishment—they become established in the networks of social and material agencies constitutive of the smart infrastructure. Thus, while it is correct to say that performing these actions is enabled by the materiality of the grid, it is also correct to say that the performance of these actions is jointly accomplished in the human/non-human amalgam that constitutes the infrastructure at any given moment. The actual performance of actions is always contextual and contingent upon the historical and agentic constitution of the smart infrastructure.

The framework (Figure 7) integrates the findings from five of the six articles[10] that form this dissertation:

- *Article #1* contributes to the framework with an understanding of the close relation between the social and the technological aspects in business continuity. Particularly, it draws attention to the reciprocity between the organizational technology and the manifestation of incidents—that is, the organizational "technology-in-use" shapes how incidents occur and with what consequences. Also, it posits that business continuity consists of cycles that iterate between periods of incident-free operations and periods of active incidents that relate to the periods of maintenance versus repair.
- *Article #2* contributes to the framework by moving toward a view of understanding and studying business continuity as "practicing continuity." Practicing continuity underscores the importance of seeing business continuity as a form of "doing" that always includes social and material components and not something that is inherently an intrinsic part embedded within humans or within technologies. Further, the article develops the idea of incidents as abrupt material reconfigurations—that is, as changing the material constitution of work and, thereof, one's possibilities of performing that work. What is significant from this view is that incidents, while they close some opportunities for acting, give rise to new demands and opportunities to reorganize work materials.
- *Article #3* contributes to the framework with the onto-epistemological foundations for a sociomaterial view of agency where possibilities for

[10] One of the articles (article #4) focuses on methodological- and quality-related aspects.

action are distributed and is productive of different conceptions of time/space. The onto-epistemological foundations provide a basis for understanding the sociomaterial constitution of the infrastructure as shifting/changing amalgams of social and material agencies. More broadly, the article provides foundations for incorporating materiality to explain social phenomena (as traditionally conceived) that is of special importance in environments entangled with materiality (such as smart infrastructures).

- *Article #5* contributes by developing the concept of infra-acting and its application to understand how the materiality of the technicians' work environment shapes their possibilities of producing reliable and continuous flows of electricity.
- *Article #6* contributes by further extending infra-acting and the onto-epistemological view of agency. It identifies the four practices and the related mechanisms that entangle the manifestation of technicians' actions and the material context of (smart) infrastructure.

In addition, I have provided in this synopsis a more elaborate discussion of the actions than what has been possible within the page constraints of conference articles (see Chapter 4). Next, I will address the research questions that yielded the above described primary findings of the study.

6.1.2 Addressing the research questions

The three research questions formed a process through which the primary contribution of this dissertation emerged. In other words, they formed stations along the research endeavor that were derived from the purpose of the study. In pursuing these questions, new knowledge surfaced that extends past research on the areas this dissertation has intersections with. Table 3 summarizes the findings derived from the research articles to address the research questions.

Table 3. Addressing the research questions

Past knowledge	*New knowledge*
RQ 1: How can organizational business continuity be understood?	
Business continuity has been primarily concerned with plans and methodologies (e.g., Botha & von Solms, 2004; Gibb & Buchanan, 2006), technological solutions (e.g., Bajgoric, 2006), and social and cognitive processes and structures (e.g., Butler & Gray, 2006; Rapaport & Kirschenbaum, 2008; Niemimaa, 2016). In	Business continuity can be understood as an achievement that becomes performed through recurrent actions. That is, business continuity is about achieving veneers of permanence and stability rather than about preserving a pre-existing state or condition.

addition, business continuity can be viewed as emerging from organizational work practices and routines (c.f., Herbane et al., 2004; Herbane 2010).	Business continuity can be approached as sociomaterial practices that involve amalgams of humans, technologies, and other materials. From this perspective, business continuity is a precarious and provisional outcome that is jointly performed rather than an attribute of any particular measure.
RQ 2: How can materiality be theorized in a smart infrastructure context?	
Theorizing the relation between the social and the technological has been described as a pendulum swinging from technological determinism to social voluntarism (Leonardi & Barley, 2008). Reflecting a broader tendency in the social sciences, materiality overall has been invisible and has only gained its significance through human perception (Dale, 2005). Sociomaterial theorizing has been suggested as a way to bring the IT artifact into theorizing (e.g., Orlikowski & Scott, 2008). Two theoretical conceptions—entanglement and imbrication—that build on broadly different philosophical assumptions provide foundations for incorporating materiality into IS studies (e.g., Leonardi, 2013; Scott & Orlikowski, 2013; Jones, 2014). In the smart infrastructure context, sensors together with IS create "dual materiality" arrangements that create new information that is constitutive of the technicians' work (Østerlie et al., 2012). The information is the new material the technicians work with (Jonsson et al., 2009).	The two main philosophical perspectives that underpin the discussions on sociomateriality differ broadly in regard to the foundational assumptions but also in the vocabulary that is used to describe and explain phenomena. The social and the material can be seen as *being entangled* or as *becoming intermingled* through interaction. Agential realism poses a radical departure from the ontological position of discrete entities that critical realism seeks to preserve. The "radical" view provides foundations for understanding the implication of technology for a broader phenomenon (e.g., such as outcomes of technology use), whereas the "conservative" view provides foundations for studying how different use patterns (e.g., routines) emerge from episodic and cumulative interactions with technology. The radical view provides an ontological view of agency where possibilities for action are relational to a material constitution of a network of agencies ("material context"), whereas the conservative view sees that possibilities for action emerge from human-technology interaction. Smart infrastructures form material amalgams of agencies. These amalgams blur the distinctions between local and non-local and give rise to topological concerns over geo-

	graphic concerns. Thus, the materiality of infrastructures enacts new realities for work to happen within its own constraints and limitations. These constraints and limitations are regulative of what work is done and how it is performed.
RQ 3: How does the performance of actions emerge in a smart infrastructure context?	
Smart infrastructures open new possibilities for work and action (e.g., Constantinides et al., 2016). The work in these settings is entangled with the materiality of the infrastructure (Almklov et al., 2014). Technicians' work has become transformed, as the materials the technological arrangements in smart infrastructure contexts produce have become the new materials with which they work (e.g., Jonsson et al., 2009; Østerlie et al., 2012; Parmiggiani and Monteiro, 2015). Smart infrastructures transform conceptions of local/non-local and the situatedness of work (Almklov et al., 2014) and enable performing tasks traditionally conceived of as highly local and situated (such as diagnosing) (e.g., Pollock et al., 2009). The material history of infrastructures limits possible development trajectories and limits agency (Venters et al., 2014).	The radical view of sociomateriality provides a foundation for situating technicians and their actions as part of the material constitution of the smart infrastructure, with implications that action and agency are historical, dynamic, polycentric, and discontinuous. That is, the technicians are *infra-acting* rather than (inter)acting. Infra-acting places matter in an active role rather than merely recognizing it as a passive substrate for action. The bottom of Figure 7 illustrates the sociomateriality of infrastructures where humans (H) and technologies (T) are part of the social (S) and material (M) context that is open to reconfigurations (as indicated by the dotted lines).

6.2 Implications for infrastructures and business continuity

The main motivation to engage in this study was the broad recognition that infrastructure continuity seemed to be a "black box." What I mean by a black box is that prior studies have largely focused on the abstract (management) frameworks and less on the internal dynamics of infrastructure continuity. Reflecting this motivation, the expectation was that by moving from distal analysis to proximal analysis we can have a glimpse of the internal dynamics of this black box, learn more about these dynamics, and, optimally, provide understanding to enact meaningful changes. Changing from a distal to a proximal analysis, and focusing on what work is done and how it is performed (Butler & Gray, 2006), foregrounded several insights that extend the research on infrastructure continuity. In short, drawing on sociomaterial theorizing, this dissertation illustrates how infrastructure continuity becomes performed in practice. In particular, it illustrates this performance by focusing on maintenance and repair work in a smart infrastructure context.

Much of the prior literature has focused on planning approaches to business continuity (Herbane, 2010). This research extends the literature by providing a performative view on infrastructure continuity. It provides a complementary rather than an alternative (or exclusive) approach. For instance, while it is critical for organizations to know what their critical functions are, the performative approach enables studying the dynamics through which those functions become performed. After all, according to Hecht (2002), business continuity "is about ensuring that the critical business functions can continue" (p. 446). The empirical analysis in this dissertation focused on one such function—the smart power grid of a power distribution company. By focusing on this specific function, I came to appreciate the importance of the maintenance and repair work the technicians perform, which had been largely absent from the discussions on infrastructure continuity. Such work is often invisible, as it is performed "behind the curtains" but also due to the common tendency to value managerial action over operational work (Graham & Thrift, 2007).

The importance of work and work practices is not wholly new to discussions on infrastructure continuity. Often, however, these are seen as ends that result from following certain methodologies (c.f., Herbane et al., 2004; Gibb & Buchanan, 2006) rather than a locus of attention. In addition, prior studies have often adopted a conceptual rather than an empirical research approach. Maintenance is recognized as one of the key steps in planning and management methodologies (Pitt & Goyal, 2004). However, what is often meant by maintenance is the refreshing of plans and measures periodically such that the documentation reflects organizational reality. Maintenance work differs from this, as it is the work that seeks to proactively avert possible breakdowns. While the empirical analysis focused on the maintenance of a specific type of infrastructure, other infrastructures are likely to not differ in this respect. Think, for instance, of all the constant maintenance work to update the software in our laptops and servers to fix software bugs and vulnerabilities. Maintenance is a *proactive* measure for infrastructure continuity.

The empirical analysis also draws attention to repair work. The proximal analysis revealed that when things abruptly break down, restoring the critical function gives rise to repair work. Repair work does not mean merely mending but also involves replacing faulty equipment, making work-arounds, and so forth. While restoring operations is, self-evidently, an important part of infrastructure continuity, there have been few attempts to conceptualize and study the restoration phase, or the focus has been on, for example, setting up response teams (Ahmad et al., 2012) or calculating optimal recovery times (Selden & Perks, 2007). The empirical analysis suggests that, at least from the technicians' perspective, the repair work builds on the same repertoire of actions as the maintenance work. As such, the findings support the recognition that effective maintenance practices are also the foundations for effective repair (Graham & Thrift, 2007).

Further, the research provides a new understanding of the concept of infrastructure continuity. When seen from a performative view, infrastructure continuity surfaces as a constant and ongoing performance that is accomplished through recurrent and joint (human/non-human constituted) actions (that form the cycles of maintenance and repair). Recognizing that performing infrastructure continuity is entangled with materiality makes it ultimately *a concept of relationship*. This view differs particularly from the view that infrastructure continuity is *a state* from where an organization diverts during an incidents (c.f., Hecht, 2002). When viewed as a state, infrastructure continuity does not appear as an issue outside of the moments of periodic reviews or incidents. After setting up the measures for infrastructure continuity, the organization functions like a set of well-greased sprockets that are merely tuned every now and then. However, analyzing the performance of work paints a more complex picture. I was surprised at the amount of effort put into ensuring infrastructure continuity outside of these moments of incidents. Infrastructure continuity seemed to be actively produced. While such performative conception of infrastructure continuity is quite different from those who take it as a state, the conception is in line with multidisciplinary research on the dynamics of infrastructures. These studies have asserted that the functioning of an infrastructure is always a precarious achievement (Graham & Thrift, 2007) and becomes jointly established in human/non-human assemblages (Bennett, 2005).

The routinized performance of work is often associated with improved infrastructure continuity performance (e.g., Stucke et al., 2008). When viewed from a distance, the recurrent actions the technicians perform depict patterns of routinized work. The findings of this research suggest that routines are not merely rigid scripts that prescribe (and bound) action but that routines are joint accomplishments established in the sociomaterial networks of agencies that, occasionally, fail. What was visible was the difference between the *ostensive* and *performative* aspects of routines (Feldman, 2000). That is, the prescriptions of routines and their actual performance often drift apart which, from an infrastructure continuity perspective, seems even wanted. Indeed, the observations suggested that strictly routinized behavior could have resulted in severe injuries if, for instance, the field technicians were to mindlessly follow the instructions of the technician at the operations center and would operate some (overly) old equipment. Thus, infrastructure continuity is likely to benefit not from having prescriptive routines but from having *flexible routines* (Leonardi, 2011). This finding further reinforces Suchman's (2007) insight on the situated nature of action. The plans (i.e., the SOPs in this case) did not function as prescriptive templates for action, but rather formed a part of the sociomaterial constitution of action. That is, they were clearly a part of constituting the space of possibilities for action but did not determine the action. Against these findings, valuing strict coherence and compliance to plans cannot be seen to necessarily lead to fault-free performance, but may actually work counter to it. Performing actions requires appreciation of the situated nature of action and the circumstances under which that action is performed. However, the construction of these circumstances under which the action is performed does not need to be an individual affair but may very well appear as a joint endeavor to which both human and non-human agencies partake.

The infra-acting mechanisms contribute to understanding the variation in organizational infrastructure continuity performance (Butler & Gray, 2006) as it relates to the aggregate performance of actions. Infra-acting suggests that the technicians' performance is relational to the four mechanisms that shape the way in which actions manifest. Thus, potential explanations of variation relate to the historical development of the grid (historicity), to its distributed (and connected) sociomaterial constitution (polycentric), and to its visibility and "openness" to dynamic reconfigurations (dynamic and invisible). For instance, the performance is likely to be quite different between a newly built smart power distribution network dug underground and an old mechanical air-wire based grid, between a power distribution network inside a building and a network in an open and exposed area, and so forth. That is, the actual performance of actions is always contingent on the material context in which they are performed. Against this background, adopting best practices for infrastructure continuity may not lead to the homogenization of practices across organizations, as some variation is likely to emanate from the context-contingent conditions relational to the mechanisms. However, these arguments should be studied further and, optimally, through comparative studies.

Further, the findings suggest that when actions are attributed to the (dynamic) human/non-human amalgam that constitutes the infrastructure, action is no longer solely attributable to the human individual but to the sociomaterial configuration of the infrastructure. It always takes more than just the human individual to perform action, and when doing so, our intentions "are always bumping into (and only occasionally trumping) the trajectories of other beings, forces, or institutions" (Bennett, 2005, p. 453). While this might always be the case, smart infrastructures seem to make this more apparent. To place materiality in a more active role means that it is not merely an extension or means of mediation but rather *constitutive* of actions. Explaining those actions thus, requires consideration of the material configuration that makes up and shapes any specific action. Thus, even if we take adaptability as the key to infrastructure continuity (Butler & Gray, 2006), the findings of this study also suggest that adaptability happens within the material boundaries and affordances of the infrastructure. These considerations are also likely to make us better equipped to explain incidents and rethink, for instance, blaming "human error" on incidents. Such considerations are likely to spur organizational politics that are “less devoted to blaming and condemning individuals than to discerning the web of forces affecting situations and events” (Bennett, 2009, cover). “Learning how to intra-act [interact] responsibly as part of the world means understanding that ‘we’ are not the only active beings—though this is never justification for deflecting our responsibilities onto others” (Barad, 2007, p. 391). Analyzing the actions rather than the actors can help us to appreciate the complex networks through which events materialize.

Last, discussions on business continuity in general originate from practitioners (Zsidisin et al., 2005). This is not unique to this area of research but also often characterizes the topics of IS scholars’ interest. Maturing as an academic discipline often rests on some form of theorizing. IS as a discipline is highly apt to deal with issues pertaining to business continuity, and, as I have shown, has already invested some effort into studying the area. However, theoretical development has been quite limited, which might explain at least partly why most business continuity discussions have remained outside of the mainstream IS outlets that value (or expect) theoretical contribution (Rowe, 2012). This dissertation contributes to filling some of the gap of lack of theorizing by connecting infrastructure continuity to sociomaterial foundations. I have found these foundations particularly insightful for studying smart infrastructures due to the entangled nature of work that takes place in these contexts. In addition, the sociomaterial perspective has enabled us to ask qualitatively different questions about infrastructure continuity. Rather than asking, for instance, what is needed for business continuity, sociomateriality draws attention to how it becomes performed.

6.3 Implications for sociomateriality research

Sociomateriality has rapidly emerged among the viable IS theories to study phenomena that are entangled with matter (Jones, 2014). In this study, I have contributed to the sociomateriality research by providing an empirical application that has been largely lacking from the literature and deemed difficult due to the abstract and highly theoretical nature sociomateriality (Leonardi, 2013; Faulkner & Runde, 2013). In particular, this research extends studies that have used the “strong” form of sociomateriality (Jones, 2014) that builds on agential realism. Sociomateriality research has often been methodologically approached in ways similar to traditional interpretive studies, and due to this approach, meanings often overshadow materiality in such a way that technologies only receive their significance and voice through human discourse (Cecez-Kecmanovic et al., 2014) rather than, for instance, being performative of those discourses themselves (e.g., Iedema (2007)). In this research, I have sought to extend sociomateriality studies and give materiality an active voice such that it appears as a constitutive part of actions rather than merely in (human) discourse. More specifically, this dissertation contributes to studies on smart infrastructures as a context for work (e.g., Almklov et al., 2014; Østerlie et al., 2012; Mikalsen et al., 2014). In addition, I have extended the ideas originating from sociomateriality to discussions on infrastructure continuity. In doing so, I have brought together streams of literature that have not been often cited together, which is one type of contribution (Locke & Golden-Biddle, 1997).

More specifically, this dissertation contributes to discussions on sociomaterial agency (Jones, 2014; Venters et al., 2014; Schultze, 2011). One of the early and novel insights into sociomateriality research was the recognition that the social and the material are constitutively entangled (Orlikowski & Scott, 2008). I extend these studies by focusing on how the social and material are entangled. The "challenge is thus to examine the thoroughgoing mutual constituency of social and material arrangements" (Mazmanian et al., 2014, p. 832). By identifying the mechanisms that shape actions, I have identified the dynamics that shape the outcomes of sociomaterial action and, occasionally, produce unexpected continuity outcomes (c.f., Coles-Kemp, 2009). The empirical analysis shows that when technicians use the technologies, their agency is not only relational to what emerges from the dyadic interaction between the technicians and technologies but from the networks of materials and relationships that the infrastructure forms as a linchpin between these various agencies. Through this linchpin, the agencies come to share a space that is not tied to that which is "local" but a matter of topological concerns (Almklov et al. 2014).

The role of history for agency has already received attention in the past sociomateriality research. Where some of these discussions have centered on the development of human perception through cumulative interactions with a certain technology (e.g., Leonardi, 2011), the empirical observations required consideration of how past practices sediment and aggregate as the (material) history of the infrastructure and of the restrictions this history bears on agency. Venters et al. (2014) have also found similar path dependency engendered by the material history of infrastructure that shapes both the use of the infrastructure and its future development trajectories. The analysis of the technicians' actions, however, suggests that the matter itself can be dynamic and that the changes affecting agency do not have to develop over prolonged periods of time but that also each action reconfigures agency. For instance, at SmartGrid Co. the technicians' possibilities for action were reconfigured by the heating of the equipment, which resulted from prior actions—that is, when they sought to restore electricity. However, as the equipment cools down, the opportunities become reconfigured dynamically. As such, the findings resonate well with the argument that "what is appropriate, what is legitimate, and what can be done are continuously tested in action, such that practice is necessarily provisional and tied to specific historical and material conditions" (Nicolini, 2009, p. 1406).

Further, the empirical observations led to incorporating vagaries as an inherent and essential part of how agency operates. On an abstract level, similar ideas are present broadly in several philosophical works. Most centrally, as I have indicated, my own thinking has been most influenced by Barad (2011), for whom vagaries, or discontinuities as she calls them, form a central feature of any development dynamics. It is certainly true that vagaries have always existed, as we have all experienced several times during our lifetime when, for instance, the handle of a hammer breaks during intense tinkering or when a bike tire goes flat in the middle of a steep downhill. Such ideas are also present in Bennett's (2009) notion of the aleatory of matter. But as the empirical findings suggest, these vagaries seem to surface as more salient and frequent in infrastructure settings that are characterized by immense complexity and inherent unreliability (c.f., Bennett, 2005). While the ideas were developed from one particular infrastructure, it is likely that this uncertainty and unpredictability is not merely tied to actions around the specific infrastructure that SmartGrid Co. maintains. The vagaries were not just incidental moments but seemed to be a part of the work the technicians performed. The manifestation of actions were largely shaped by encountered vagaries that had influenced how they perform their work. Alternative ways to perform certain actions had become established for cases when, for instance, during an outage the remote control fails and the technological "arms" have to be substituted with human arms. This suggests that vagaries may have broader implications for technology use and the formation of practices than what is often recognized.

Last, and more broadly, the research contributes to discussions on non-anthropocentric conceptions of agency (Barad, 2007; Bennett, 2009; Knappett & Malafouris, 2008) that have been found useful in analyzing smart infrastructure failures (Bennett, 2005). Focusing on polycentric agency extends earlier sociomaterial discussions that often "privilege the role of human actors, rather than see agency as emerging from relations between human and nonhuman actors (i.e., the social and technological as mutually constitutive of our practice)" (Cecez-Kecmanovic et al., 2014b, p. 819). I have found the conception particularly useful when explaining the technicians' actions, as adopting such position seemed more veracious to my observations. Actions are rarely determined by the technicians, or at least, are constituted by a host of other human/non-human agencies, which also transposes the indexicality of action. From the non-anthropocentric view, agency is not an attribute of any individual human or "thing" (c.f., Leonardi, 2011; Introna & Hayes, 2011) but an attribute of the sociomaterial configuration that constitutes a particular situation (Barad, 2007). It thus allows one to move away from and circumvent questions as to whether or not a technology "acts" and whether it can be ascribed with agency. Instead, we come to see the networks of agencies and their relations that both enable and constrain action and change. Similar ideas have also been presented by Mazmanian et al. (2014), for whom "[r]econfiguration, then, denotes the process in which new assemblages of agency emerge" (p. 832). It is likely that other scholars will find the conception of agency useful when moving from studying dyadic interactions with information systems to infrastructures as proposed by Tilson et al. (2010a,b) and Monteiro et al. (2013)

6.4 Implications for practice

While the focus of this dissertation is on theoretical development, some practical implications can be derived from the findings. These implications are broad suggestions and considerations for organizations' managers.

The findings of the research underscore several important practical considerations for infrastructure continuity, as follows:

- *Maintenance is not just one type of work and activity among others but is key to proactive infrastructure continuity*. As such, organizations should realize that well-managed infrastructure continuity starts from well-organized maintenance. However, settling for well-organized maintenance is not sufficient.
- *Infrastructure continuity is always a temporary achievement that is prone to break down*. Complacency is not an option; rather, organizations need to be ready to repair the infrastructure once it fails to restore its functioning.
- *Well-organized maintenance forms the foundations for the repair efforts*. Replacing broken devices, updating software, coordinating responses, and so forth are all founded on the maintenance work.
- *Pay close attention to the operational work and not just to strategic and managerial work.* While strategic and managerial decisions are likely to influence those conditions under which the operations become performed, it is the actual work through which infrastructure continuity is performed.
- *Performing the maintenance and repair work is always sociomaterial rather than social (or material).* That is, while it is certainly true that humans can achieve a whole lot more with technologies than without, it is also true that technologies achieve much more with humans. When thinking about continuity, organizations should consider sociomaterial arrangements that produce continuity outcomes rather than seeking to disentangle the entangled performances into their constitutive parts. Actions may thus provide a more useful analytical unit in lieu of processual analysis, which often seeks improvements in a piecemeal fashion by focusing on the individual components constitutive of organizational processes.

- *Do not simplify the causes of incidents but seek to analyze the complex webs of actors and actions behind the event*. What seems at first to be human error or a technological failure is likely to have more complex origins. In an infrastructure context, actions are jointly performed, meaning that causes are not simply the result of *an effect* but the outcome of a cascade.

Further, when analyzing and comparing an organization's infrastructure continuity performance to other organizations, managers need to recognize that their current performance is not merely determined at present but is also historically contingent. That is, the smart infrastructure cannot be often built afresh but rather has to be reworked gradually and iteratively. The gradual and iterative reworking is always conditioned and relational to the aggregated history of the past choices the matter embodies.

6.5 Considerations for the evaluation of the quality of the study

Qualitative research comes in many forms. As I have indicated, the empirical part of this research follows ethnographic tradition and builds on agential realist foundations (see "3: Research approaches"). While several IS scholars have conducted research from similar methodological grounds (e.g., Østerlie et al., 2012; Mazmanian et al., 2014; Cecez-Kecmanovic et al., 2014), the relative newness and novelty of agential realism (Jones, 2014) is likely to evoke questions on evaluating the quality of this study. To avoid being judged incorrectly, Davidson (2002) instructs that "it is incumbent on the researcher to outline those criteria by which he or she believes the research project should be judged" (p. 357). Without explicit considerations, there is a risk of what Lincoln et al. (2011) refer to as "Catholic questions directed to a Methodist audience" (p. 175): "We use this description […] to refer to the ongoing problem of illegitimate questions: questions that have no meaning because the frames of reference are those for which they were never intended. (We could as well call these 'Hindu questions to a Muslim,' to give another sense of how paradigms, or overarching philosophies—or theologies—are incommensurable, and how questions in one framework make little, if any, sense in another)" (pp. 175-176).

Over the years, IS scholars have brought forth a plethora of quality evaluation criteria. These include criteria for qualitative research in general (Sarker et al., 2013), for positivist studies (Benbasat, 1987; Dubé & Paré, 2003), for interpretive studies (Klein & Myers, 1999; Walsham & Sahay, 1999), for critical research (Myers & Klein, 2011), for critical realism (Wynn & Williams, 2012), and for ethnographic research (Myers, 1999; Golden-Biddle & Locke, 1993; Guba, 1981). As the list suggests, none of these criteria is directly applicable to agential realism, which differs from positivist, interpretive, critical, and critical realist research traditions (these differences are discussed in “3.1: Philosophical considerations”). In article #4 I have outlined a criterion that identifies three key differences in agential realism in comparison to interpretive stance (see “5.4: Article #4: Sociomaterial ethnography”). These three factors together with generic guidance on ethnographic research (Myers, 1999) form the quality criteria of this study.

In relation to *sociomaterial entanglement*, I have founded the research on the ontological foundations of agential realism. In doing so, I have focused on actions as sociomaterial entanglements to explain the infrastructure continuity performance in a smart infrastructure context. I have been particularly attentive to the performativity of materiality on actions. I have adopted a *performative* view to materiality. In what I have termed as infra-acting (note the gerundial form), materiality is an active, dynamic, and agentic part of the sociomaterial constitution of actions. I have recognized as being *part of the phenomenon studied.* That is, the outcomes of this research are jointly produced with the informants such that I, as a researcher, form a constitutive part of the results. Despite my passive observer role, I have acknowledged that to observe “is to attend to persons and things, to learn from them, and to follow in precept and practice” (Ingold, 2014, p. 387). However, recognizing my part in the results does not mean that the categories and explanations I have helped to enact are completely arbitrary or that anything could have been possible. Rather, they are the outcome of the practices of knowing in which myself, my empirical material, the theoretical apparatus, and the informants entangle. That is, “the fact that we make knowledge not from outside but as part of the world does not mean that knowledge is necessarily subjective (a notion that already presumes the preexisting distinction between object and subject that feeds representationalist thinking)” (Barad, 2007, p. 91).

From agential realist perspective, the question of objectivity/subjectivity is not one of a dichotomy between two extremes of the same pole but relates to matters of practices of knowing. “Hence objectivity requires an accounting of the constitutive *practices* in the fullness of their materialities, including the enactment of boundaries and exclusions, the production of phenomena in their sedimenting historiality, and the ongoing reconfiguring of the space of possibilities for future enactments” (emphasis mine) (Barad, 2007, p. 391). As Rouse (2004) explains, “[i]t is central to Barad’s concept of phenomena that their repeatability is differential; what matters is not the exact reproduction of the same sequence of events, but the reproduction of a significant pattern despite various differences among instances of the same phenomenon” (p. 147). Thus, to produce similar phenomenon (read: outcomes) is not to perform the exact same steps or to perform those steps in exactly same context, but “to try to produce the same pattern in different circumstances, and perhaps by somewhat different means” (Rouse, 2004, p. 147). While reproducing the exact same circumstances (and same sociomaterial constitution) of this study is never possible in the forever enfolding world, learning to produce similar patterns under different circumstances is likely feasible and useful for explaining the patterns in other contexts. “Although each context of study is different, the dynamics and relations that have been identified and theorized can be useful in understanding other contexts” (Feldman & Orlikowski, 2011, p. 1249).

In evaluating the quality of the ethnographic fieldwork, I build on Myers’s (1999) four broad considerations: “(a) contribution (novelty and capacity to convince the journal editorial board of this), (b) rich insights (one way to address this being to consider whether it contradicts conventional wisdom), (c) significant amount of data collected (involvement of the researcher on the field to get data; contextualization, multiple stakeholders perspectives), (d) sufficient description of the method” (Rowe, 2012, p. 474).

In considering the *contribution* of this study, I have sought to justify the contributions by showing how the findings of this study relate to prior studies. In constructing and positioning the findings, I have drawn from multidisciplinary literature on infrastructures, on business continuity, and on sociomateriality (see “2: Informing literature and theoretical elements”). In doing so, I have cited streams of literature that are “streams not typically cited together” (Locke & Golden-Biddle, 1997, p. 103). Further, this dissertation builds on already published articles, which is an indication of being able to convince one’s peers of the (novelty of) contributions.

In justifying the need for the contribution, I have drawn on the strategy of problematizing (Alvesson & Sandberg, 2011) extant conceptions and the understanding of infrastructure continuity. In framing the contributions of the study, I have (re)conceptualized infrastructure continuity and discussed its implications for prior research. Thus, the contributions “are not predictions in the conventional sense but may be better understood as principles that can explain and guide action” (Feldman & Orlikowski, 2011, p. 1249).

In considering the *rich insights* of the study, I have shown how the findings contrast with some of the established and conventional wisdom of infrastructure continuity (see “6.2 Implications for infrastructures and business continuity”). Most centrally, adopting sociomateriality as a theoretical lens allowed me to reconsider the established conceptions and pose different qualitative questions on the nature of infrastructure continuity. Rather than focusing on the means for infrastructure continuity, I have studied infrastructure continuity as (sociomaterial) performance. In considering the *significant amount of data collected*, I have conducted a lengthy period of fieldwork as a participant observer. The fieldwork produced considerable empirical material that forms the foundations for the empirical part of this research (see “3.3: Ethnographic fieldwork”). In providing a *sufficient description of the method*, I have outlined the details of the research process (see

“3.3: Ethnographic fieldwork”), described the empirical material, included illustrations of the empirical material (see “Appendix A: Illustrating empirical), and provided a detailed account of the ethnographic site (see “4: Empirical site: SmartGrid Co.”).

7 CONCLUSION

The heavy armour becomes the light dress of childhood; the pain is brief, the joy unending. (Schopenhauer, 1970/1850, p. 132)

In this dissertation, I have sought to increase understanding on how the business continuity of infrastructures (i.e., infrastructure continuity) becomes performed by adopting a sociomaterial and performative stance. The main motivation for the research was the recognition that infrastructure continuity has largely remained as a "black box," which has been studied from distance but lacked proximal analysis on its internal dynamics.

In exploring the topic, I have used both conceptual and empirical research approaches. The empirical part was studied through an ethnographic inquiry that focused on a particular type of a smart infrastructure—a smart power grid—and analyzed the actions technicians perform to ensure its continuity. That is, more broadly, I have focused on the work that is invested in ensuring the continuity of the organization's critical function. The analysis builds on sociomaterial theorizing that starts from the assumption that "there is no social that is not also material, and no material that is not also social" (Orlikowski, 2007, p. 1437). This dissertation contributes to discussions on infrastructure continuity and sociomateriality.

7.1 Primary contributions

The primary contribution of this dissertation is the conceptualization of infrastructure continuity as performed through ongoing and recurrent work. From this performative perspective, infrastructure continuity is not (solely) a matter of technologies or of human ingenuity but is a joint accomplishment that becomes established in/through an amalgam of human/non-human agencies that constitute the infrastructure. Specifically, this dissertation shows the significance of maintenance and repair for infrastructure continuity.

Further, this dissertation contributes to discussions on sociomaterial theorizing by extending the conceptions of non-anthropocentric and polycentric forms of agency by providing the concept of infra-acting. *Infra-acting* situates agency as a part of the material constitution of an infrastructure. It recognizes agency as not an attribute of any individual "thing" (be it human or non-human) but as an attribute of the particular configuration of the entangled whole—the infrastructure. In addition, this research contributes to sociomateriality research with an empirical application of agential realism that has been mostly lacking.

While this research has primarily focused on theoretical development, it has practical implications. Most centrally, the research draws attention to the importance of operational maintenance and repair work as part of the dynamics through which infrastructure continuity becomes accomplished that have often been overshadowed by concerns of managerial governance. Further, the study seeks to increase managers' understanding on the mechanisms that influence their infrastructure continuity performance by drawing attention particularly to the role of history.

7.2 Future research

During the research process, several new concerns surfaced. Some of these concerns led to rethinking the focus and scope of the study, while others remained in the background. Here, I wish to discuss some of the concerns I have learned during this lengthy process and, hopefully, pave the way for future research on the topic.

As this research has focused on increasing understanding, a natural question that follows is: What do we now do with the new understanding? As I have discussed, one of the implications of this new understanding is to better grasp some of the internal dynamics of infrastructure continuity. While the dynamics identified here (i.e., mechanisms) may explain the variation in organizations' infrastructure continuity performance, they tell little about *improving* organizational performance. Thus, in the light of these mechanisms, how could the performance be improved?

Following past studies, one of the possible ways for improving infrastructure continuity relates to planning methodologies. The findings of this study pose that more consideration be given when developing methodologies that should be studied further. Particularly, if we consider infrastructure continuity to be sociomaterial, then our *methodologies, too, should be sociomaterial*. More specifically, methodologies should explore whether (and how) it is possible to develop frameworks for continuity that would not analytically disentangle the organizational processes into constitutive social and material parts in order to focus improvements on discrete entities but rather find ways to treat them as entangled actions that take into account the fact that things receive their boundaries and properties only in relation to particular action.

Further, focusing on the performance of infrastructure continuity posed questions on the *organic* development of infrastructure continuity. By organic development I mean the kind of learning and transformation that takes place in everyday life and through everyday experiences and encounters. The importance of organic development is often neglected when the focus is on externally stipulated improvements that are imposed from top to down in align with organizational governance structures. Any possibilities for organic development are then denied or at least treated as unimportant and insignificant. While it is clear that reactive learning from mistakes is only feasible as long as the learning exceeds the related costs, there are also other ways in which improvements may take place. One of the areas that I have merely touched upon here is the role of organizational stories of incidents for such improvements. Orr (1996) has shown insightfully how such mundane, prosaic, and even entertaining stories form the basis for organizational learning. However, we know little about how these vicarious learning experiences transform the organizational actions and reactions in relation to incidents.

Studying the mechanisms and the context-specific manifestation of actions across multiple sites could yield understanding on why certain organizations perform *better* than others. As I have focused on a single site (as is typical for ethnographies), the findings of this research do not afford comparative analysis across sites. While it is likely that the same mechanisms are also prevalent in other sites, their salience for performance might vary across sites. Studying the relative salience across sites and their influence on infrastructure continuity would necessitate and justify multi-site studies.

Last, in relation to sociomaterial theorizing, the study raises some further concerns on the very nature of materiality. Sociomaterial theorizing, and agential realism in particular, has drawn attention to the role of matter in "social" (as traditionally conceived) affairs. However, applying the sociomaterial lens to study a materially heterogeneous environment such as that of smart infrastructure would benefit from going beyond the recognition that "matter matters" toward improved understanding of *how different kinds of matter matter*.

From a sociomaterial perspective, we, as humans, also become a part of the amorphous and non-striated material world. To this extent, Rouse (2016) argues that that "Barad's post-humanism should still recognize significant differences between human and other agencies" (p. 1). Incorporating his insights could thus further improve the explanatory power of sociomaterial theorizing. Stein et al. (2014) have already moved toward this direction by introducing emotions into sociomateriality research. However, focusing on identifying the specific traits of humans is not sufficient (and risks bringing back the humanism Barad so opposes) and should also theorize about the materiality of "things". The challenge of such theorizing is to not resort to essentialist statements about "things" and to treat them as constitutively entangled while recognizing that certain matters matter more than others (even if it is only in relation to a certain practice). Bennett (2009) has provocatively and purposefully anthropomorphized material things to surface relations and flatten the flat-rooted hierarchies between humans and things. Future research should investigate these arguments further.

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APPENDIX A: ILLUSTRATING EMPIRICAL MATERIAL

Knowing ⇔ Historicity and sedimentation of practices
“*[name redacted] also explained that some muuntamo [converter] in the downtown [City] are fairly old. In those cases, if there is a need to make connections to those, it might be that the field engineers refuse to do changes due to safety. The systems might be so old that they can’t safely operate them. In that case, the judgement has to be made by them, not the operator. The operator sees the muuntamo only as one dot in the IS. However, due to their experience they might be able to know what type of muuntamo a specific place is*.” [Field note, 20141119]
Harmonizing ⇔ Polycentric and agentic constitution
“[name redacted] called to a customer who had called to customer service and told he saw a big bang and lightning bolt. He wanted to confirm whether it was a pylväs [pole] or a koppi [box]. She (the customer) confirmed it was a pylväs [pole]. He called to field engineers who were closest to the location. They soon called back and told - “Orava huilailee kannella” [a squirrel is taking a nap on top of the converter]. They could not really see what had happened since the squirrel was on top of it [the pole converter] and they could not see there. He [the technician] then called to [name redacted] who has a koriauto [a skylift car]. He was sent to confirm what had happened and what should be done next. After the call they [the technicians] started joking about the “huilailee” [taking a nap]. “3,5 kA tuli ylivirtaa et taitaa vähän huilailla” [3,5kA overcurrent so the squirrel must take quite a long nap] [name redacted] told.” [Field note, 20141103]
Diagnosing ⇔ Dynamic and invisible agencies
“The operator went to tell to [name redacter] that yesterday there had been an outage, “maasulku” [ground circuit] in the air cable network. However, the automatic recovery had fixed the outage. When the automatic system works there will be only an alert in the IS showing where the problem has occurred. This time, it had been really short, only some milliseconds. I asked from [name redacter] more about the event and he explained probably some mouse got himself killed again or so. They normally drop from the lines quickly after they have become electrocuted. Sometimes they get stuck by the electrocution and then the critter does not fall but stays on the line. In such case, the automatic system fails to bring back the energy as the critter is still on the power line. [name redacted]

repeated what many others had told – the operators have to wait for one-two minutes after such outage before trying to turn on the power again remotely. This is due to the possible overheating in the components. They are allowed to do the reconnection remotely ones and then they have to send someone to check the status. It is also possible that during the one minute time, the burnt critter body will become burned so that it drops from the line, even if it was stuck after the electrocution. However, yesterday, whatever had caused the incident had only caused a very short problem." [Field note, 20141119]
Vagaries ⇔ Precarious and discontinuous material foundations
"I talked with [name redacted] and he told the IS had been updated some days ago and everything seemed to be OK, but the remote controlling did not work [to all places]. When they had tried to reroute the power, nothing had happened. Interestingly, [name redacted] told there was another problem which was uncovered simultaneously. A remote controlling of another place in the archipelago did not work. [name redacted] explained they had a radio link through which the switch was controlled, but there was another one in the archipelago that was so far away from [SmartGrid's] premises that the signal had to be regenerated. Now this antenna tower where the repeater was, was without power. Electricity had gone down and despite that there were batteries, the batteries had died. [name redacted] showed from the IS how the place was marked red in the system —red does not imply anything good. However, as [name redacted] explained, at the moment there was no real a problem since only the repeater was down." [Field note, 20141028]

APPENDIX B: SELECTED PUBLICATIONS

1.

Article #1: Niemimaa, M. (2015). "Interdisciplinary review of business continuity from an information systems perspective: Toward an integrative framework," *Communications of the Association for Information Systems* (37:4), pp. 69-102.

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Interdisciplinary Review of Business Continuity from an Information Systems Perspective: Toward an Integrative Framework

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Abstract:

Hackers, malicious users, system malfunctions, and other incidents can disrupt organizational IS and cause severe organizational losses or even impact societies as a whole. In this paper, I review interdisciplinary literature on business continuity from an information systems (IS) perspective to increase understanding on how organizations can prepare for and respond to incidents. I use a narrative review approach with descriptive elements to review 83 peer-reviewed papers published between 2000-2012 across a wide array of journals and disciplines. I identify themes across the past contributions, join the currently isolated streams of literature under a concept of IS continuity, and identify research gaps in the current knowledge. The results suggest that one can understand past contributions in terms of four themes that emerged from the literature: (1) social aspects as IS continuity enabler, (2) technology as IS continuity enabler, (3) salience of IS continuity, and (4) models that improve IS continuity. To move toward an integration of the past research, and to pinpoint research gaps, I present an integrative framework. Further, the research contributes to forming an IS continuity community to facilitate cooperation and communications among scholars sharing a common interest.

Keywords: Business Continuity, Literature Review, IS Continuity, IS Security, IS Operations, Incident Preparations.

The manuscript was received 11/05/2013 and was with the authors 5 months for 2 revisions.

1 Introduction

As organizations and information systems (IS) increasingly commingle, any incident with organizational IS may cause significant organizational damage. Examples of past incidents where IS caused significant organizational damage are plentiful and vivid. Based on an international industry survey (730 validated responses) conducted in 62 countries, 40 percent of the organizations were disrupted by an incident in IS during 2012 (Business Continuity Institute, 2013).

Widely reported large-scale incidents help explain the severity and impact of incidents and the related complexity and difficulty organizations face preparing for them. For instance, in 2012, Hurricane Sandy caused significant damage to many countries. However, of interest here is the large scale damage it caused to IS. Due to heavy flooding, water flowed to data centers located on the east coast of the US, which shutdown servers hosted in the facilities and caused damage that took weeks to recover (Thibodeau, 2012). The damaged servers included the Huffington Post, BuzzFeed, and Gawker that, due to the incident, failed to provide services to their customers (Talbot, 2012a). Interestingly, as the hurricane was raging thousands of miles away, a movie theater's ticket sales in Finland came to a halt. The hurricane had caused an outage in Microsoft's cloud servers in the US and forced the company to move its U.S.-based customers to European cloud servers, which overloaded the European servers and finally halted the movie theater's electronic ticket sales system, which happened to use the cloud servers in Europe (Haapalainen, 2012). In overall, organizations that used cloud-based services (see Yang & Tate (2012) for a review of cloud based services) seemed to fare better than those relying on more traditional solutions (Talbot, 2012b).

But not only extreme weather cause such incidents. In 2011, one of the largest Nordic service providers (Tieto Co.) experienced an incident due to a problem in their data storage system, which damaged the company itself and a large number of other organizations dependent on their IS. Although the company has not disclosed the incident's exact details, the details of those affected are better documented. According to a post incident report conducted by the Swedish Civil Contingencies Agency (2011), more than 50 public and private organizations were directly affected by the incident in Tieto's IS. One of the affected organizations was an organization (or its IS) that handles electronically prescribed medicines in Sweden. Due to the incident, citizens could not obtain their medicine. While it is unclear whether the incident caused any patient injuries, hospital pharmacies and pharmacies in sparsely populated areas in particular found the incident inconvenient. The incident's impact further grew when the organization responsible for the electronically prescribed medicines also lost its public website due to the Tieto incident and could not disseminate information to pharmacies efficiently. The incident shows how an incident in one organization's IS caused damage that affected much of Swedish society (Swedish Civil Contingencies Agency, 2011).

In addition, hackers and malicious users cause incidents. Harmful and costly attacks that prevent online payments and access to websites, referred to as denial-of-service attacks, that hacktivists (i.e., hackers with ideological goals) and other malicious groups cause are numerous. One severe, high-impact attack was an attack allegedly carried out by the hackitivist group Anonymous. A denial-of-service attack cost Paypal, Visa, and Mastercard millions of pounds as their customers were unable to use their services (Daily Telegraph, 2013).

Even though the incidents' source largely differs in each case, the incidents caused severe organizational consequences. The above examples also illustrate the breadth of damage an incident may inflict and the possible costs associated to an incident. As such, it is not surprising that IT technology-related incidents are the leading causes of concerns among managers (Business Continuity Institute, 2013).

Despite the organizational significance and the central role IS managers have in preparing organizations for these types of incidents (Pitt & Goyal, 2004), "IS research provides little guidance for managers who must evaluate investments in this area, craft policies, train personnel, and adjust organizational structures to enhance business continuity" (Butler & Gray, 2006, p. 218). Past contributions are spread to multiple IS subdisciplines, such as IS security (e.g., Botha & von Solms, 2004; Stanton, 2005), IS operations (Butler & Gray, 2006), and IS strategy (Gibb & Buchanan, 2006). The research's fragmentation likely explains its absence from the mainstream management and IS literature (cf. Pearson & Clair, 1998). However, a multidisciplinary group of scholars interested in business continuity (hereafter BC) have studied ways in which organizations can prepare for incidents of all sort, including those related to IS. Research on BC has appeared in several other disciplines such as supply chain management (Norrman & Jansson, 2004;

Zsidisin, Melnyk & Ragatz, 2005), water & wastewater management (Moyer & Novick, 2012), healthcare (Iyer & Bandyopadhyay, 2000), crisis, disaster and emergency management (Lindström, Samuelsson, & Hägerfors, 2010a; McConnell & Drennan 2006), strategic management (Herbane, Elliott & Swartz, 2004) and business history (Herbane, 2010). Hence, looking beyond the boundaries of IS discipline to see how the business continuity appears in discussions of other disciplines may have a positive impact on related discussions in IS.

In this paper, I review the past literature on BC from an IS perspective to increase understanding on 'how organizations can prepare for and respond to incidents'. I see an incident here broadly as an event that is not part of an IS's standard operation and which causes or may cause an interruption to, or a reduction in, an organization's ability to continue business (adopted and adjusted from International Organization for Standardization, 2011). I acknowledge the aforementioned question is not the only question to which literature on BC has potential to contribute to. However, it is a timely question for three reasons. First, organizations' operations have increasingly become dependent on IS (Orlikowski & Scott, 2008). Second, technology's ever-increasing complexity increases the possible ways in which it can fail. Third, the interconnectedness of IS and the increase of Internet-connected systems that pervade everyday life (e.g., the "Internet of Things" (Atzori, Iera, & Morabito, 2010)) increases the possibilities for malicious attackers to cause incidents.

In this research, I identify common themes across isolated streams of literature and identify routes for future research. In other words, I structure the past to prepare for the future (Webster & Watson, 2002). I present an integrative framework to integrate the past literature and pinpoint gaps in knowledge. I use the "IS continuity" concept to denote the reviewed literature and to contribute to forming a community around the shared research concern to increase communication and collaboration among scholars.

The paper is structured as follows. In Section 2, I overview business continuity and its various definitions as background information. In Section 3, I summarize the reviewed papers and outline the methodological choices for collecting, analyzing, and structuring the literature. In Section 4, I present the analyzed literature's central contributions and, in Section 5, I discuss the findings and make suggestions for future research. In Section 6, I conclude the paper.

2 Background: Business Continuity Definitions and Uses

Before discussing IS continuity specifically, I overview business continuity (BC) by introducing various BC definitions, the similarities they share, and the breadth of research that characterizes the multidisciplinary discussions around BC. This discussion serves two more specific purposes apart from introducing BC's background: first, the definitions form a basis for the integrative framework in Section 5. Second, indicative examples of the breadth of current research on BC motivate narrowing the review to a certain part of BC literature: to IS continuity.

Although the term "business continuity" implies a tight connection to businesses, the research on business continuity studies organizations of all types. Following the paths paved by practitioners (Zsidisin et al., 2005), scholars interested in business continuity study ways to prepare for incidents of all types. Central to research on BC is accepting the underlying assumption that, even though each incident may exhibit some unique characteristics, they also share some common patterns that enable organizations to prepare for them.

Various definitions, uses of BC, and scopes of what BC covers exists (see Table 1 for explicit definitions). While the definitions are in broad sense concerned with the continuity of organizational operations, they express some significant nuances. One can categorize the definitions by the way the BC concept appears as part of the definition to three groups. The first group refers to BC as an organizational capability to resist and recover from a disruption of any kind. Asgary and Mousavi-Jahromi (2011) relate BC to an organization's capability to withstand power outage; thus, the capability can be improved with power outage mitigation technologies (e.g., uninterrupted power supply (UPS)). Similarly using the BC concept, Momani (2010) argues that "[b]y considering such (legal) requirements the organization will both follow existing requirements and improve its business continuity capability" (p. 277). In this sense, the capability is a continuum instead of a mere binary (i.e., the capability exists or does not exist). To indicate the continuum, Lindström et al. (2010a) developed a staircase maturity model for indicating the different levels of business continuity maturity.

The second group refers to BC as a means to achieve a given (organizational) end (i.e., as a model/methodology to achieve a certain goal, such as establishing a policy (e.g., Momani, 2010)). As I discuss in Section 4, much research on business continuity has focused on different approaches (e.g., models/methodologies, frameworks). As such, BC as a concept and the means to achieve a certain end have become intermingled.

The third group refers to BC as an organizational state in which an organization is under normal conditions and from which it diverges after an incident. As such, BC represents an organizational state in which an organization is able to continue operations; thus, maintaining the state becomes crucial. Moyer and Novick (2012) provide a good example of such use of the BC concept:

> *"…it is also crucial to plan for delegating special authority that may be needed to maintain business continuity while responding to an incident"* (p. 38, italics mine).

While the individual definitions seem varied, they share similarities and interrelate with one another. The first and third groups share similarities in that the BC is already an outcome of a certain processes, whereas the second group sees BC as the means to achieve those ends. The first and third groups, however, differ in their view of BC because the first group sees BC as a capability that is a continuum, whereas the third group sees it as a state that is closer to a binary. Viewing BC as a binary state does not mean that all organizations would be same in relation to BC but that organizations differ in the degree of their ability to *maintain* the state. For the first group, who see BC as a capability, the capability is then the ability to *maintain* operations/business, which is also a state.

As a subject of study, BC is multidisciplinary, which one can illustrate with some examples that present some of the BC literature's extremes: Conseil, Mounier-Jack, and Coker (2008) examine the effects of pandemic influenza on public and private organizations' BC and argue that most pandemic influenza research only focuses on public health systems; Hassanain and Al-Mudhei (2006) examine ways to minimize the effects of facilities renovations and focus on office building renovations and on organizations' capability to sustain BC; Kadam (2010) apply the BC to the individual level of analysis and contribute to literature by suggesting steps that each (private) person should take to prepare for unexpected events, such as death, injury, or severe illness.

BC originates from IT recovery but has shifted to a holistic view (as the above discussion suggests) (Herbane, 2010). Although preparing organizations for any sort of incident is significant, this wide range of topics covered under the "BC" concept has led to what Copenhaver and Lindstedt (2010) refer to as a "cacophony of voices"; that is, "an unfocused assortment of ideas, approaches and advice" (p. 165) that make up the research around BC. Although Copenhaver and Lindstedt (2010) and Lindstedt (2008) seek to create a new discipline (that of BC), I suggest an alternative way is to identify currently disjointed streams of literature and unite them to achieve more focused contributions in the future by setting up communities of interest that facilitate discussion and cooperation among those with an interest in BC.

So far, IS scholars interested in BC have contributed to a wide array of IS subdisciplines. In addition, the wider multidisciplinary community has contributed with closely related research: in the disaster management discipline, Iyer and Bandyopadhyay (2000) discuss the significance of health management information system (HMIS) on healthcare organizations' (HCO) BC, and Moyer and Novick (2012) describe their efforts of creating a supporting IS for BC in the water and wastewater management discipline. These contributions suggest there is a disjointed community of scholars who share a common concern on the part that IS has for organizations' BC. I use the term IS continuity throughout the rest of this paper to denote this stream of BC literature.

Table 1. Definitions of Business Continuity

Type of use	Author	BC definition
Organizational capability	Bajgoric (2006)	"The term 'Business Continuance' [business continuity] has been introduced in order to emphasize the ability of a business to continue with its operations even if some sort of disaster occurs." (p. 450)
	Bajgoric & Moon (2009)	"The term, 'business continuity' (business continuance, business resilience) refers to the ability of a business to continue with its operations even if some sort of failure or disaster occurs." (p. 74)
	British Standards Institution (2006)	BC is the "strategic and tactical capability of the organization to plan for and respond to incidents and business disruptions in order to continue business operations at an acceptable pre-defined level" (p. 1).
	Castillo (2005)	"Business Continuity is the ability to retain a revenue stream through a crisis." (p. 18)
	Herbane, Elliott, & Swartz (2004)	Authors use Sharp's (2002) definition: "business continuity is about anticipating failures and taking planned and rehearsed steps to protect the business and its stakeholders' interests" (p. 439).
	International Organization for Standardization (2012)	BC is a "capability of the organization to continue delivery of products or services at acceptable predefined levels following disruptive incident" (p. 2).
Organizational means to achieve an end its normal facilities are restored after a disruptive event" (p. 16).	Arduini & Morabito (2010)	BC is "a framework of disciplines, processes, and techniques aiming to provide continuous operation for "essential business functions" under all circumstances" (p. 122).
	Benyoucef & Forzley (2007)	Authors use Security and Privacy Research Center's definition: "business continuity determines how a company will keep functioning until
	Botha & von Solms (2004)	Authors use the definition of Rubin (1999): "It [business continuity] can be defined as the process of examining an organisation's critical functions, identifying the possible disaster scenarios and developing procedures to address these concerns" (p. 329).
	Momani (2010)	"Business continuity is a continual improvement process that starts with establishing business continuity policy and ends with recommendations from the management review to keep business continuity plans up to date." (p. 278)
	Rapaport & Kirschenbaum (2008)	"'Business Continuity" (BC) is not the outcome of a work organisation's coping with an emergency, but is rather a social process leading to survival." (p. 339)
	Shaw & Harrald (2006)	BC is "the business specific plans and actions that enable an organization to respond to a crisis event in a manner such that business functions, sub-functions and processes are recovered and resumed according to a predetermined plan, prioritized by their criticality to the economic viability of the business. Business continuity includes the functions of business resumption and business (disaster) recovery.".
	Swartz et al. (2003)	Authors use Herbane et al.'s (1997) definition: "business continuity is defined as a management process that identifies an organisation's exposure to internal and external threats, and which synthesises hard and soft assets to provide effective prevention and recovery whilst enabling competitive advantage and value system integrity" (p. 66).
An organizational state to continue operations	Speight (2011)	"Business continuity is a management process that identifies potential factors that threaten an organization and provides a framework for building resilience and the capability for an effective response." (p. 529)
	Basel Committee on Banking Supervision (2006)	BC is "[a] state of continued, uninterrupted operation of a business".
	Roitz & Jackson (2006)	BC is about "ensuring uninterrupted operations even after a disastrous event" (p. 7).
	Hecht (2002)	BC "is about ensuring that the critical business functions can continue" (p. 446).

3 Methodology

In this paper, I use a narrative review with some descriptive elements (King & He, 2005). King and He view narrative and descriptive reviews along a continuum of different types of approaches to analyzing past research. The narrative approaches present "verbal descriptions of past studies" that are "of great heuristic value, and serve to postulate and advance new theories and models…and direct further development in a research domain" (p. 667). The descriptive approaches:

> *introduce some quantification" and "often involves a systematic search of as many relevant papers in an investigated area, and codes each selected paper on certain characteristics, such as publication time, research methodology, main approach, grounded theory, and symbolic research outcomes (e.g., positive, negative, or non-significant) (p. 667).*

I chose the narrative approach because I sought to integrate past contributions to an IS continuity framework and direct further developments of the topic (King & He, 2005). Thus, I present the paper's contributions (see Section 4) and the elements of the integrative framework (see Section 5) in a more elaborate fashion (in narrative-like format) than is typical for descriptive reviews. Accordingly, I illustrate the previous studies' main themes and the related elements of the integrative framework with interesting examples instead of systematically listing all studies under each result category. Further, to present the distribution of research approaches in the IS continuity literature, to present the distribution of papers per theme, and to indicate where and when the most research efforts have been made, I include quantifications that are typical for descriptive studies.

3.1 Finding and Choosing the Papers

I found 83 academic peer-reviewed papers published across a wide range of disciplines that fitted my scope (see Appendix C for a complete list of reviewed papers). The scope included papers written in English, that were published between 2000-2012, that study BC in organizational context, and that provide contributions that cover socio-technical aspects of BC (i.e., IS continuity). I chose the 2000-2012 period because BC shifted from planning approaches to management approaches during this period (Herbane, 2010). In addition, the period length is well over the average time span in similar papers (Siponen & Willison, 2007).

More specifically, following Webster and Watson (2002), I first reviewed the two top IS journals *(i.e., MIS Quarterly and Information Systems Research).* I discovered only one paper that discusses BC (i.e., Butler & Gray, 2006) instead of just briefly mentioning the concept (e.g., Backhouse, Hsu, & Silva, 2006; Gordon, Loeb, & Sohail, 2010; Smith, Winchester, Bunker, & Jamieson, 2010). Next, I searched for peer-reviewed papers using the term "business continuity" in well-known search engines (Google Scholar, ACM Digital Library, ProQuest, AIS Digital Library, and EBSCO). After uncovering the first set of the literature, I used the snowballing technique to uncover rest of the papers (Webster & Watson, 2002). As such, I was able to collect a comprehensive selection of interdisciplinary academic literature on BC.

To narrow the uncovered literature to fit my scope, I reviewed all potential papers at the topic level to determine whether they covered BC in an organizational context, after which I analyzed their abstracts. I included all papers on organizational BC published in IS outlets. I read and analyzed other potentially suitable papers to identify whether they covered the topic from an IS perspective. I give IS here a wide interpretation. Rather than viewing IS as synonymous for IT artifact, I use IS in a socio-technical sense to cover both social aspects (e.g., attitudes, skills, values, the relationships between people and authority structures) and technical aspects (processes, tasks, and technology) and their correlative interactions (cf. Bostrom & Heinen, 1977). This interpretation would likely fail to meet the expectations of those who advocate (returning to) an IT artifact-centered view on IS (e.g., Benbasat & Zmud, 2003) but is likely to resonate for those advocating a wider interdisciplinary view on IS (e.g., Galliers, 2003; Desanctis, 2003) and work system view (Alter, 2003). Therefore, IS continuity represents the part of the business continuity literature that is concerned with the continuity (i.e., preparing for and responding to) of a socio-technical assemblage (i.e., the IS).

I could discard some papers easily; some I could not do so easily. For example, I deemed Conseil et al. (2008) and Hassanain and Al-Mudhei (2006) to not cover IS continuity. When there was uncertainty, I further discussed the paper in question with another scholar to verify whether it reflected her understanding of an IS contribution. When there was disagreement or uncertainty, I included than excluded the paper. The resulting collection of papers forms the basis for IS continuity.

Figure 1 illustrates the distribution of papers per year[1] and the number of papers published across disciplines (see Appendix A for a full list of journals and categorization of journals to disciplines).

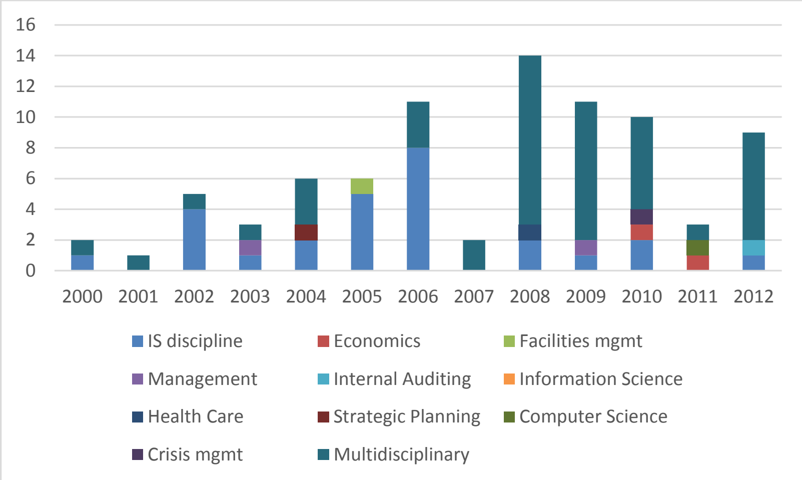

Figure 1: Distribution of IS Continuity Papers Per Year

3.2 Analyzing and Categorizing the Literature

To thematize the papers, I classified the contributions into themes to identify the most common themes across contributions, which I did by avoiding predefined categories. Instead, the themes emerged from the papers themselves (Bacon & Fitzgerald, 2001). Allowing the themes to emerge was necessary because no predefined categories existed due to the topic's multidisciplinary nature. Instead, the themes resulted from an iterative literature analysis in the spirit of hermeneutic analysis (Myers, 2004; Boell & Cecez-Kecmanovic 2014).

The fundamental tenet of hermeneutic analysis is that correct understanding emerges from the interplay between the parts and the whole (Klein & Myers, 1999). The "whole" refers here to the understanding that one gains through reading and analyzing the papers; that is, the "parts". The interdisciplinary focus of the research further supported using hermeneutics because "(i)nterdisciplinary integration brings interdependent parts of knowledge into harmonious relationships through strategies such as relating part and whole or the particular and the general" (Stember, 1991, p. 4). To understand the whole, I read each paper through and wrote notes down about it. Subsequently, I coded each paper by using qualitative coding techniques (Miles & Huberman, 1994). The notes included emerging categories and other notes that I felt were important for the research (e.g., interesting findings, representative papers for each category). For example, the codes included "methodologies", "frameworks", "lifecycle" that, I assimilated after several iterations of hermeneutic interpretation and qualitative coding into a single category. Section 4 presents the emerged categories, their definitions, and their respective content.

Before moving to discuss the results of the review in more detail, I note other research that has embarked to review some aspects of BC literature that I uncovered during the review process. Herbane (2010) provides a detailed trajectory of BC by following its development from the 70s' "disaster-recovery" approaches to developing an approach coined as business continuity management (BCM). Adkins, Thornton, and Blake (2009) conducted a content analysis on business continuity planning literature: they collected 2500 publications (academic, trade publications, media articles, and government/legal publications) published between 1997-2007. They used random sampling to choose 75 papers from each

[1] Interestingly, the quantity of published research between 2008-2010 is equal with the quantity of published research during the rest of the analyzed period. In a yearly survey of key issues for IT executives, BC was ranked relatively highly (ranks 3,6,4) between the same period (Luftman & Ben-Zvi, 2010). The authors suggest that "(t)he likely reason for its [BCs] high ranking during the recession is the inherent risks due to the reduced investment during the recession" (p. 10). The popularity of the topic among IT executives might also explain the high number of research during the 2008-2010. Unfortunately, no comparison data was available for the rest of the review period (2011-2012) that could be used to correlate whether current recession has had similar effects on BC popularity among IT executives. However, at least the number of published studies seems to be lower than during the earlier recession.

category (N = 300), after which they used random sampling to select 28 papers for intercoder reliability. Their findings suggest business continuity planning is mostly used for natural disasters, electronic disasters, and terrorism/warfare events. Unfortunately, the authors do not disclose the categories' details, so it is only possible to speculate whether they categorized all the IT- and technology-related publications as "electronic disasters".

4 Results

In Section 3, I describe the review process I used to uncover, analyze, and classify the IS continuity literature. In this chapter, I present the results of the review process. First, I discuss the reviewed papers' research approaches and their theoretical basis. These two parts provide a more generic view on methodologies and theoretical orientations that IS continuity scholars have found particularly fruitful. Last, I discuss the thematized IS continuity contributions in detail.

4.1 IS Continuity Research Approaches

To assess and categorize the research approaches used in the IS continuity literature, I used the following categorization scheme:

- Cases: research that studies single or several sites over a period of time to provide a detailed and particular account of some interesting organizational change or development process.
- Conceptual: research that is argumentative and makes no or little reference to empirical data to back up its arguments.
- Experiment: research that studies one or more controlled groups. The studies may take place in a laboratory or in a real-world setting.
- Interview: research that collects data only through any type of qualitative interviews.
- Survey: research that collects data through questionnaires.

I adopted the above categorization scheme from Chen and Hirscheim (2004) and adjusted it. Chen and Hirscheim categorize research approaches to six categories: (1) survey, (2) case study, (3) laboratory experiment, (4) field experiment, (5) action research, and (6) others. The adjustments were necessary due to the nature of IS continuity literature. The categorization I used does not distinguish between laboratory and field experiments due to the low number of experiment studies (only one field experiment; i.e., van de Walle & Rutkowski (2006)). The case studies, in addition to academic case studies (cf. Yin, 2003), include practitioner-oriented case studies that Orlikowski and Baroudi (1991) call descriptive work: "the researchers attempted no theoretical grounding or interpretation of the phenomena; rather, they presented what they believed to be straightforward 'objective', 'factual', accounts of events to illustrate some issue of interest to the information systems community" (p. 5) (see Thornton, 2008, for example). Further, I categorized conceptual studies that make no or little references to empirical material as conceptual instead of "other" as Chen and Hirscheim (2004) categorize them. Lastly, I added studies that relied purely on qualitative interviews as a separate research approach (interview) because they did not fit to any of Chen and Hircscheim's (2004) categories. Where possible, I categorized the papers in line with their authors own assessment of their research approach.

Because many papers omit explicit discussion on the adopted research approach, I had to infer their approaches. My analysis suggests that the most popular research approach IS continuity studies have adopted is conceptual that makes no or little references to empirical data. Appendix B provides the details of the analysis. Further, because most papers do not discuss data collection and analysis, I do not discuss these aspects here.

4.2 IS Continuity Use of Theories

Theory use in IS continuity can be mostly characterized as "loose" (Walsham, 2006) or even as "no theory" (Siponen & Willison, 2007). Exceptions are Butler and Gray (2006), who draw on mindfulness; Van de Walle and Rutkowski (2006), who draw on fuzzy set theory; Pheng, Ying, and Kumaraswamy (2010), who draw on rational choice theory, normative theory, and cultural-cognitive theory; and Lindström, Harnesk, Laaksonen, and Niemimaa (2010b), who draw on soft-systems methodology (SSM). Other studies review the prior literature on business continuity to define conceptual relations. The extent of connection to past literature varies across the papers. Indeed, the business continuity niche journal's *(i.e.,* *Journal of Business Continuity & Emergency Planning)* policy explicitly states that papers"need not display in-depth knowledge of previous academic work in the field" (Henry Stewart Publications, 2013). Clearly, there is no common core theory or set of core theories in IS continuity.

4.3 IS Continuity Contributions

The literature on IS continuity broadly deals with ways to improve the continuity of organizational IS. I discuss the four themes that emerged from the data for rest of the paper: 1) social aspects as IS continuity enabler, 2) technology as IS continuity enabler, 3) salience of IS continuity, and 4) models that improve IS continuity.

I categorized each paper to a single theme. While some papers fit unambiguously under a certain theme, some are more ambiguous to categorize. For instance, Rapaport and Kirschembaum (2008) clearly emphasize that social processes lead to BC, and Bajgoric (2006, 2010) clearly emphasize that technology enables BC. Thus, they exemplify the first two emerged themes, respectively. However, those categorized as models (theme 4) include studies that advocate certain steps that organizations should take, which might include both social and technological aspects. More specifically, these steps included choosing a suitable technology to mitigate continuity problems or arranging training for personnel to prepare them to act in a preplanned manner during an incident. As such, the models would connect with the two categories of social and technology, but, in lieu of extensively discussing either aspect, the discussion is held at a superficial level and as a single part of a larger set of steps. Lastly, while each of the reviewed papers discuss the salience (e.g., why the continuity practices are important and why organizations should engage with those practices) of their study topic, the papers in theme 3 ("salience of IS continuity") mainly emphasize the importance of organizational continuity preparations. These interrelations and interdependencies suggest possibilities exist for integrating the themes.

In lieu of exhaustively listing every paper and their respective contribution, I discuss certain papers' contributions that illustrate the themes in line with the paper's narrative approach. As such, I focus on describing the themes rather than on describing individual papers (Webster & Watson, 2002).

4.3.1 Social Aspects as IS Continuity Enabler (11 Papers,13,3%)

Despite advancements in the literature emphasizing BC's socio-technical nature (Herbane et al., 2004), according to Smith (2003), social aspects have been under represented in the literature. Even though technologies have a central role in contemporary organizations (Orlikowski & Scott, 2008), "it is people who actually deal with business continuity and crisis" (Smith, 2003, p. 28). Past research suggests that the social aspects influence incident preparations at the individual and collective levels but also that response for an incident is contingent on social aspects. In this section, I elaborate on the individual-level social aspects and the collective-level social aspects. I then discuss the contingencies between social aspects and incident response.

Influencing the central organizational actors is viewed crucial for IS continuity. Top management that is reluctant and disinterested about IS continuity may significantly impede preparations (Seow, 2009). As such, scholars have repeatedly emphasized the importance of organizational leaders' commitment to BC (e.g., Gibb & Buchanan, 2006; Kite & Zucca, 2007; Lindström et al., 2010a; Seow, 2009; Stanton, 2005). Inducing fear on the executives by describing the consequences of not adequately preparing may act as motivator. Indicating sanctions that result from non-compliance to regulatory (continuity) requirements, showing management ignorance to good management practices, indicating gaps to competitors' practices, showing lost customer opportunities, and appealing to executives personal motivators (and fears) may all motivate executives to sponsor IS continuity projects (Seow, 2009).

Preparing for incidents requires that many organizational roles participate in the implementation project (Kendall, Kendall, & Lee, 2005). Walch and Merante (2008) examine the appropriate staff size to manage continuity projects and explain how to calculate it. They conclude that organizations should consider their industry, their number of critical systems and applications, the complexity of their IT infrastructure, and the quantity of their data centers and their geographical locations when deciding the staffing. However, past studies suggest that not only the quantity of the social actors but also their individual-level qualitative differences affect how well an organization is prepared for an incident. The social traits and skills of the person responsible for managing the IS continuity implementation have been found central for success (i.e., Shaw & Harrald, 2006; Wong, 2009). Wong (2009), building on his own experiences as practitioner, identifies the strategic skills IS continuity managers need. He emphasizes the importance for proactive leadership that "enables organisations to anticipate the threats to corporate objectives and competitiveness, and develop responses in relation to the long-term implications of a crisis" (p. 67).

In addition to the individual, studies also emphasize the collective social aspects' importance. The prevailing (collective) culture of the social setting in which the preparations to an incident are embedded influences an organization's preparations. King (2003) sees that a "correct" collective continuity-aware culture ensures that continuity plans and guidelines are maintained Thus, an organization that has a continuity-aware culture acts in a "correct" and BC-aware way, whereas an organization without such a culture "buries its head in the sand" (McConnell & Drennan, 2006, p. 69). Thus, collective behavior becomes inscribed in the culture in such a way that actions that support organization's preparedness for incidents follows; in other words, culture is an enabler. However, Sawalha and Anchor (2012) and Sawalha and Meaton (2012) view culture differently: that is, as an inhibitor. The authors argue that societal culture can significantly inhibit whether an organization adopts organizational BC. Further, past research on collective social aspects suggests an organization's social conditions fostered during "normal" times not only influence its preparations but are projected into the moment of incidents. Butler and Gray (2006) argue that organizations should foster conditions of collective mindfulness in lieu of focusing on detailed plans and guidelines. Thus, collective mindfulness implies a change from implementing detailed plans and guidelines that should govern employees' response actions during an incident (i.e., mindless response) to preparing high-level instructions for responding and focusing on enhancing organization's overall ability to perceive early cues of incidents, interpret them, and respond appropriately (i.e., collective mindfulness) (Butler & Gray, 2006). Lastly, Rapaport and Kirschenbaum (2008) argue that "Business Continuity (BC) is not the outcome of a work organisation's coping with an emergency, but is rather a social process leading to survival" (p. 339). They suggest that an organization's ability to respond to an incident lies in the social process influenced by such social aspects as social ties and social networks that influence employees' adaptability to incidents and positively contribute to organizational survival.

4.3.2 Technology as IS Continuity Enabler (16 Papers, 19,3%)

Reflecting the roots of business continuity, many organizations still perceive continuity as a technical issue (Cerullo & Cerullo, 2004). However, past research suggests that technology, in respect to continuity, has a dual role. First, technologies themselves are to reduce or remove incidents altogether. From this view, technologies themselves are the preparations for incidents. Second, technologies are to enhance or enable preparations and responses to an incident. From this view, technology mediates and enhances preparations and responses to an incident. I elaborate on both of these views in this section.

Some scholars have viewed improving organizational technology through more-advanced technological solutions as a way to prepare for incidents. Bajgoric (2006) argues that "information technologies (IT) have been recognized as business continuity enablers" (p. 451). Hence, Bajgoric (2006) argues that, to enable business continuity, organizations should invest in continuous computing infrastructure. Continuous computing infrastructure builds on "always-on" computing that uses several technological advancements, such as on 64-bit computer architecture instead of 32-bit architecture (Bajgoric, 2006). In a similar manner, Ceballos, DiPasquale, and Feldman (2012) suggest organizations should use advanced networking technology called dense wave division multiplexing (DWDM) to help them 'address current datacenter challenges specific to business continuity and security in light of the potential for equipment failure, fiber cuts, floods, fire, or massive power grid blackouts, as well as denial of service and terrorist attacks' (p. 147). However, organizations cannot focus on IT without accounting for technology's dependency on other resources. Asgary and Mousavi-Jahromi (2011) found, based on a survey (n = 482) conducted in the Greater Toronto Area in Canada, that power outages are a major threat for organizations, and especially for those dependent on IT. Even though their results show that many respondents had not implemented measures to mitigate power outages, organizations are willing to pay for mitigation efforts, but they prefer options that are less costly, environmentally friendly, and take little (physical) space. Power supply technology called uninterrupted power supply (UPS) may help organizations to prepare for and mitigate the impact of power outages (Asgary & Mousavi-Jahromi, 2011). Thus, using (advanced/additional) technology may serve as an effective way to prepare for and avert certain incidents altogether.

Past research suggests technology may also support preparation. To support business continuity planners to make preparations, van de Walle and Rutkowski (2006) developed a decision support system with which planners can individually assess the likelihood and impact of incidents and compare their assessment to those made by other organizational continuity planners. Based on a field experiment, the authors conclude that the planners they studied were more satisfied with the decision process and showed more agreement with the group decision when they used the decision support system than when they did not. In addition, their data shows that the planners' assessments were less extreme than without the system's aid. Husband (2007) describes an IT system that John Lewis Partnership developed to consolidate 200 separate business continuity plans into a single system which supported the preparation process by ensuring information stored in the system was accurate and up-to-date. In addition, other studies exist that highlight the supportive role IT plays in preparation. However, these studies depict the development of the IT as a straightforward and do not pay attention to the details of the implementation/adoption and/or mention the IT as part of other steps the organizations took to prepare for incidents: Alesi (2008) describes the use of a Web-based intranet solution at Lehman Brothers "to create customised incident response and planning tools that connect in real-time to authoritative, up-to-date sources of data, using the same look and feel familiar to users" (p. 218); Thornton (2008) the use of IT "that provides a consistent and rapid risk assessment capability" (p. 51) at the Australian Customs Service and Australian Quarantine and Inspection Service; and Moyer and Novick (2012) the use of an IT "toolbox" ("a detailed guidance document that supports a utility seeking to develop a BCP [business Continuity Plan], a word processing template, and a series of online training modules for additional guidance in working through each BCP development step" (p. 38)) to help managers plan for water and wastewater system business continuity. As such, technologies are effective in mediating and enhancing organizational preparations for incidents.

Lastly, past research suggest that technologies are not only effective in preparing for incidents, but also significant in responding to incidents. Heng, Hooi, Liang, Othma, and San (2012) and Roitz and Jackson (2006) describe two different but interrelated cases in which an IT-enabled telecommuting work contributed to BC. Heng et al. (2012) designed and implemented a telecommuting system and evaluated (post implementation) the system's influence on organizations' preparedness for incidents. Based on the results, 64.1 percent of the informants strongly agreed that the telecommuting positively affected the organizational preparedness. Roitz and Jackson (2006) describe telecommuting at AT&T and argue that telecommuting is an important contribution to BC. AT&T's IT-based telecommuting enabled the company's employees to access its IT systems and enabled the formation of virtual teams during hurricane Katrina while the normal office premises were unreachable. While these improvements on organizational incident response are positive side effects of telecommuting, Sapateiro, Baloian, Antunes, and Zurita (2011) developed an IT system, a mobile collaboration platform, solely to enhance incident response. They designed the system to increase a team's "capability to assess, make decisions and act upon disruptive situations through better communication, data sharing and coordination' (p. 166). Still, even though scholars have embarked to find technologies that support the response, in general, "further research should be conducted to validate the tool(s) during actual disruptive situations" (Sapateiro et al., 2011, p. 179).

4.3.3 Salience of IS Continuity (18 Papers, 21,7%)

"Without business continuity and crisis management, lives are lost" (Power & Forte, 2006, p.17). Although this quotation represents one of the extremes, some reviewed papers focus on emphasizing the salience of business continuity practices for organizations. Prior studies have found that previous incidents, especially those that have had a high impact, and hypothetical incident scenarios can be powerful ways to communicate the BC's importance to other scholars and practitioners. These studies are significant for IS continuity for two reasons. First, they emphasize preparation's importance and complacency's likely/possible consequences. Second, they illustrate the type of harmful events organizations in the past have been able to avert through the a priori preparations and effective response. Although past incidents are likely a bad mirror of the future, they can support the assumption that preparations pay off even if all possible future scenarios cannot be predicted or extrapolated based on the past events. As such, drawing attention to the importance of preparation through examples of disastrous events that have already unfolded or to those that may unfold in the future, the studies serve an important role in motivating other organizations to start making preparations or to improve existing ones.

September 11 in 2001 (i.e., "9/11") represents one of the large-scale, catastrophic events that put significant demands on organizations' incident preparations (or lack thereof). According to Berman (2002), those organizations that had done a priori preparations "fared far, far, far better than those who did not" (p. 30). Although, the event had catastrophic effects on all parts of organizational life for those affected, what is of interest here is the impact on organizational technology. Recovering organizational technology resources after the incident took much longer than most organizations had anticipated (Berman, 2002).

Organizations had to find ways to do business without IT. Many technologies, whether advanced or less advanced, had failed and required alternative ways of working and alternative IT to keep the business running. The organizations' IT that supported business processes had to be mapped to alternative manual procedures until the IT had been replaced (Berman, 2002). Alonso (2001) argue much of the preparations organizations had in place to mitigate an event such as 9/11 could be traced to past incidents. According to him, organizations had already learned from the 1993 World Trade Center Bombing and from Y2K problem; as such, they avoided significant data loss from 9/11. Thus, his arguments suggest that the preparations organizations made in the past helped to mitigate impact of an adverse event that greatly differed from the previous events.

Whereas 9/11 is an example of a high-impact incident, Ernest-Jones (2005) argues that organizations should not only focus on grand-scale incidents and contemplate on the idea that preparations for grand-scale incidents would help them to also cover smaller incidents. Indeed, Ernest-Jones (2005) quotes Ernest & Young's specialist who argues that "it's the middle ground that causes most problems. That's where the least successful enactment of (BC) plans usually is" (p. 8).

Further, past incidents may also serve to prepare organizations for different types of incidents that at first seem unrelated but that share some common aspects. In IS security, Hinde (2005) discusses how Lea & Perrins, a company that produces Worcestershire sauce, experienced severe reputational damage that was caused by their competitor's product recall as illegal dye had gone into the competitor's product that also happened to be a Worcestershire sauce. While Lea & Perrins had not used the illegal dye, "[f]or most consumers Worcester sauce is Lea & Perrins...[s]o any scare story about contaminated Worcester sauce automatically implicated Lea & Perrins in many consumer's minds" (Hinde, 2005, p. 19). Using the product recall as an example of an incident with cascading effects, Hinde (2005) argues for the importance of IS continuity practices, even for preparing for technological incidents. Through continuity practices, organizations should realize and account for the wider context in which they reside; "to assume that you can look at the risks facing the computer center in isolation from the neighboring environment is risky to the point of foolhardiness" (p. 18). In addition, Stanton (2005) suggests incidents in IT are different from other incidents in the nature of impact and risk and are, therefore, changing how organizations should view BC. He argues it takes less than 60 seconds to ruin a company's reputation or to cripple its business in the "digital networked economy". Unfortunately, it is unclear how precisely the digital networked economy differs from other types of environments in this respect.

Lastly, Herbane et al. (2004) studied six U.K.-based financial firms and found initial evidence that organizations can derive strategic value from the capability to continue operations in the event of incident and from the capability to restore from an incident quicker than competitors. As such, their results suggests that it makes sense businesswise to enhance organizations BC—both by making preparations and improving response for incidents.

4.3.4 Models That Improve IS Continuity (38 Papers, 45,8%)

The most common contributions from scholars interested in IS continuity have been various models through which organizations improve IS continuity. As discussed earlier, the BC concept and the models, as means to achieve BC, have become so intermingled that they have become nearly synonymous. Scholars have brought forward models/frameworks that can be categorized roughly into two approaches: 1) business continuity planning (BCP) and 2) business continuity management (BCM). As the name implies, BCP is a planning approach, whereas BCM[2] is a:

> *holistic management process that identifies potential threats to an organization and the impacts to business operations those threats, if realized, might cause, and which provides a framework for building organizational resilience with the capability of an effective response that safeguards the interests of its key stakeholders, reputation, brand and value-creating activities. (International Organization for Standardization, 2012, p. 2)*

Most of the BCP models comprise six phases (Pitt & Goyal, 2004, p. 88; see also Turetken, 2008, p. 376, for similar categorization): (1) project initiation, (2) risk assessment/business impact analysis, (3) design and development of the BCP, (4) creation of the BCP, (5) testing and exercising (ranging from document reviews to realistic exercises (Gibb & Buchanan, 2006)), (6) maintenance and updating (I ask readers to

[2] Although the definition is from British Standard 25999. the definition is widely accepted and used among scholars and practitioners (see, e.g., Bajgoric, 2006; Herbane, 2010; Sawalha & Meaton, 2012).

view the details of each step from the original research papers). Where the risk assessment phase often follows normal risk management practices (Gibb & Buchanan, 2006), the business impact analysis (BIA), used to calculate business impact of unavailability of resources (Messer, 2009), is more BCP specific. The calculation can be divided into two types of measures: (1) recovery time objective (RTO) and (2) recovery point objective (RPO). RTO is the "the desired amount of time it takes to recover", whereas RPO is "the distance in time between the last restoration point (the last full backup typically) to the current point in time" (Cervone, 2006, p. 176). The BCP phases are transitive and should be followed in consecutive order. According to Cerullo and Cerullo (2004), through these phases, three interdependent objectives should be realized: (1) "identifying major risks of business interruption', (2) "develop a plan to mitigate or reduce the impact of identified risks", and (3) "train employees and test the plan to ensure that it is effective" (p. 71). Further, despite that the abstracted phases of BCP are universal, "every organization needs to develop a comprehensive BCP based on its unique situation" (Cerullo & Cerullo, 2004, p. 71).

Botha and von Solms (2004), based on "a study of various existing methodologies and each one's strong and weak points", developed "a seven-phase BCP methodology" (p. 331). Their suggested methodology has four "sub-lifecycles": (1) the backup cycle, (2) the disaster-recovery cycle, (3) the contingency planning cycle, and (4) the continuity planning cycle. Their methodology differs from the above six-step model in that, through the sub-lifecycles, small and medium-sized organizations can adopt and adjust the methodology to their needs and resources. For instance, with resource constraints, their methodology recommends small organizations to focus merely on the backup cycle and to leave the creation of plans to larger organizations with more resources. Thus, the methodology is customizable to fit even the smallest organizations, and it recognizes differences in the needs of different organizations, something that has not been explicitly addressed in most of the other life cycles.

BCM models extend the BCP models and, thus, represent the next generation in the continuity approaches' evolution (Herbane et al., 2004). Although most BCM models also incorporate a part that focuses on planning (Gibb & Buchanan, 2006), BCM emphasizes embeddedness; that is, "BCM is then not merely 'a plan' but constitutes the organisational processes of leadership, commitment to which may be seen operating at individual and group levels" (Herbane et al., 2004, p. 442). BIA can have important role in moving an organization toward embeddedness. As Messer (2009) argues, BIA can be used as a tool to leverage enterprise-level group thinking, which results in viewing BC as part the of the business-as-usual; that is, as embedded. Further, Selden and Perks (2007) argue that a structured BIA may align BC with organizations strategic goals. Thus, the BCM extends the BCP approaches by drawing attention not only to the steps for creating plans, but also to changing social and organizational aspects. Even though the models depict a linear process (see Smith, 2003; Strong, 2010; Gibb & Buchanan, 2006; Tammineedi, 2010), empirical findings suggest the process is "messy, probably two-directional and incremental" (Herbane et al., 2004, p. 77).

Scholars have also focused on some specific aspect of the IS continuity and provided models for those tasks. Kendall et al. (2005) extend continuity models and use a theatre metaphor to illuminate and deepen understanding of the importance of exercises and evaluation; Nosworthy (2000) provides a model for assessing the risks IS continuity should account for; Turetken (2008) provides a multi-criteria model for choosing the most appropriate location for a backup IT infrastructure; Freestone and Lee (2008) provide a model to "survive" a BCM audit by illuminating the process that auditors take when assessing organizational BCM; McLoughlin (2009), building on an international BCM standard, the International Organization for Standardization's (2013) ISO 22301 standard, provides steps to preparing organization's BCM that are in accordance with the standard; Tammineedi (2010) elaborates the steps and requirements of the same ISO 22301 standard; Wan (2009) develops a framework for integrating BC plans and IT service management and argues that "the continuity plan needs to be integrated with ITSM (IT Service Management) if an organisation is going to be able to manage fault realisation and return to normal business operations" (p. 41); and Lindström et al. (2010b) provide a model for learning from past incidents based on systems thinking.

As the above discussion on BCP and BCM suggests, the focus in the past research on models has been on guiding organizations on making preparations for incidents rather than guiding the actual response that organizations take after an incident.

To summarize, the discussion on the contributions of past research point to some disunity and disagreement among scholars on the ways in which organizations should prepare and respond to incidents. While using IT is recognized as being indispensable for contemporary organizations in preparing for and responding to incidents (see "technology as IS continuity enabler" subsection), technology alone likely does not suffice for cases when the technology fails. Further, scholars have questioned whether planning approaches (see "Models that improve IS continuity" subsection) that assume "likely future scenarios can be probabilistically anticipated and that individuals can understand, or at least imagine, their potential impact" (Butler & Gray, 2006, p. 218) are feasible and suggest focusing fostering social aspects that promote adaptability (see "Social aspects as IS continuity enabler" subsection). However, scholars such as Stucke, Straubm, and Sainsbury (2008) argue that "adaptability is certainly indispensable in a crisis, but that, overall and primarily, organizations should depend on their well-tested plans for recovery and not on ingenuity" (p. 160) (see "Models that improve IS continuity" subsection). Halliwell (2008) differs from the binary opposition between plans and social ingenuity and suggests a response is contingent on the incident and that these contingencies require not only different approaches in responding but also in preparing (i.e., that, for some incidents, there is a need to prepare plans, while others can rest on social ingenuity). Interestingly, Berman (2002), even though clearly emphasizing plans' importance, describes how organizations successfully responded to 1993 World Trade Center bombings without pre-made plans with mere social ingenuity. According to him, the success meant organizations became confident they were sufficiently prepared to respond to future incidents as well, only to be proved wrong by 9/11 (see "Salience of IS continuity" subsection). However, rather than accounting for the qualitative differences (and similarities) between the two incidents, he argues, the environmental circumstances during the incidents, such as the weekday of the incident, access to buildings, loss of lives, transportation, and the availability of recovery sites, influenced the response's effectiveness (i.e., the response that was effective in the 1993 bombing event was not (as) effective in 2001). That is, organizations should not sink into a mindset of complacency only because some earlier incident was averted successfully but should sustain a (pro)active attitude toward incidents. Thus, while it is likely that the technologies, the plans, and the social aspects are complementary and contingent on the incident rather than mutually exclusive, any incident preparations require active and ongoing activity to be successful. In Section 5, I focus on integrating the themes and point out certain gaps that need to be addressed to move further toward a unified, integrated view.

5 Discussion and Suggestions for Future Research

I began this paper with the organizational problem of incidents and ask how organizations can prepare for and respond to incidents to guide the review. To address this question, I reviewed multidisciplinary literature on BC in which I focused on topics of interest for IS community. These contributions form the foundations for IS continuity.

The purpose of the multidisciplinary approach I used here was to cross the boundaries of disciplinary domains in order to increase understanding and to provide new ideas from the IS reference disciplines and beyond. The literature analysis shows that the topic is both an intra-IS disciplinary and a multidisciplinary concern. This research's interdisciplinary nature brings together the multidisciplinary fragmented ideas to enrich IS research on business continuity with ideas from other disciplines (Stember, 1991).

Next, I suggest an integrative framework for IS continuity that brings the multidisciplinary discussions closer. The framework has two purposes: (1) it provides an integrated overview of the literature and how the different areas of interest fit together, and (2) it provides a basis for discussing some of the gaps that need to be addressed to move further toward a unified view.

5.1 Integrating the Themes of IS Continuity

Building on and extending the reviewed literature, Figure 2 illustrates the IS continuity integrative framework. I start by clarifying concept definitions related to the framework. I then describe each part of the framework and provide illustrative examples from the past research, which is in line with the narrative approach I have adopted for this study.

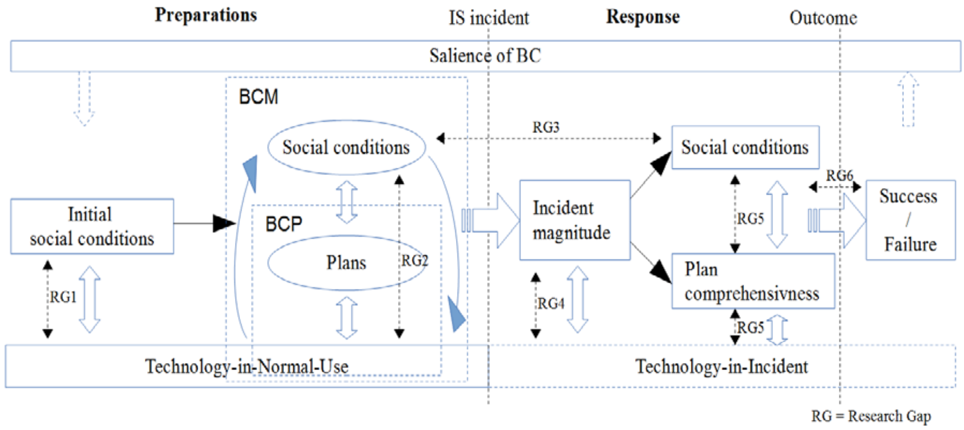

Figure 2. Integrative Framework for IS Continuity

In line with the past definitions (see Table 1), the scope of IS continuity in the integrative framework covers the preparations for and responses to an incident. The wide scope consolidates the views of those authors who limit the scope to preparations and those who extend the scope to also cover the response to an incident. A narrower scope would mean excluding some of the definitions and research from the framework. The preparation phase covers all aspects of preparation—from the initial decision to initiate a project to a point when an event befalls—and the response phase covers all aspects of response—from detecting and initially reacting to the incident to the point when the organization has recovered (or not recovered). Thus, the integrative framework promotes a holistic view of IS continuity rather than isolating the preparations and response to separate domains of interest and research. The holistic view makes sense because the preparations for incidents and how they are enacted in responding to an incident are intimately linked. From this view, there are three “continuity states” instead of a single “continuity state”: (1) the preparations, (2) the response, (3) and the outcome. The continuity capability, then, is an organization’s ability to maintain preparations state (see left side of Figure 2) and to successfully recover from the response state (see right side of Figure 2). In addition, this view differentiates “IS continuity” itself from the models that increase the capability—a separation that has been blurry in past research. To summarize, the framework itself does not pose limits as to whether the IS continuity is an organizational capability, a methodological, means-to-an-end approach, or an organizational state of operations; they fit to different parts of the framework.

In contrast to prior literature, the integrative framework explicitly differentiates between technology-in-normal-use and technology-in-incident (see “Technology as is continuity enabler” subsection in Section 4). The technology-in-normal-use refers to the IT technology organizations use to run their routines. The technology-in-normal-use includes those IT technologies the organization has implemented to support and increase the continuity of normal business operations and those designed especially to support the incident preparations. Past IS continuity research has made contributions to both types of technology, such as “always-on computing” (Bajgoric, 2006), DWDM technology (Ceballos et al., 2012), and databases for consolidating all continuity plans (Husband, 2007). The technology-in-incident refers to technology available and in use during an incident. An incident induces changes to organizational technology. For instance, an incident that cripples an organization’s primary IT infrastructure changes the organizational technology in use and simultaneously a need for additional technology not in use before the incident (or using the same technology differently) arises. The organization has to use its secondary IT infrastructure (if the organization has made such preparations) and take into use the technology designed for responding to an incident, such as the mobile collaboration tool (Sapateiro et al., 2011) and other diagnostics and troubleshooting tools, or shift altogether to alternative ways of working, such as telecommuting (Heng et al., 2012; Roitz & Jackson, 2006).

5.1.1 The Preparations

The integrative framework takes a socio-technical process view of continuity that brings closer the social and the technical aspects of continuity (see “Technology as IS continuity enabler” and “social aspects as

IS continuity enabler" subsections in Section 4). The process starts from initializing organizational preparations for incidents, which is influenced by organizational social conditions at individual and collective levels, such as top management's state of mind, wider societal culture, and organizational culture. Past research suggests that management needs to be convinced of the salience of proactive preparations (for instance, by using top management's "weak points" or by appealing to past incidents (Seow, 2009)) and that the wider societal culture may inhibit initiating preparations at the organizational level (Sawalha & Meaton, 2012), whereas "correct" organizational culture may promote the initiation (King, 2003). Thus, appealing to descriptions of past incidents and studies that in other ways underline the significance of IS continuity preparations are likely to be a useful source for both the top managers and for those who need to convince the top managers (see "Salience of IS continuity" subsection in Section 4). Further, an organization's experience of its technology-in-normal-use may influence the initial social conditions in it (indicated as the blue arrow between initial social conditions and technology-in-normal-use in Figure 2). For instance, as a simple and general example, those organizations that perceive their technology-in-normal-use to be unreliable are more open to the idea of initiating measures to reduce the number of incidents and hasten recovery. Similarly, documented cases of past incidents specific to a certain technology (for instance, break downs of certain enterprise resource planning (ERP) software) are likely powerful motivators.

After the preparations have been initiated, the quest is to create/improve plans, technologies, and social conditions (the black arrow in Figure 2 indicates the transition from initiation to improvement). This is the primary domain of BCP/BCM research (see "Models that improve IS continuity" subsection in Section 4) as indicated by the dotted line boxes in Figure 2. I do not claim that BCP research would completely neglect the social conditions but indicate the main thrust of the research. Similarly, I do not claim that BCM would completely neglect the response part but indicate that the main thrust has been in the embeddedness of organizational BC measures as part of organizational social conditions.

The BCP/BCM models provide authoritative guidance to preparations. The models provide guidance to creating plans, choosing technologies, and facilitating "correct" social conditions (such as "correct" culture (King, 2003; Sawalha & Meaton, 2012) and commitment to BC (Herbane et al., 2004)). More-specific models support organizations in more-specific tasks, such as in choosing the appropriate backup IT infrastructure location (Turetken, 2008), "surviving" an audit (Freestone & Lee, 2008), or training and exercising the social actors for incidents (Kendall et al., 2005).

As a means of preparation, organizations seek to employ advanced technologies that potentially move the occurrence of incidents further into the future (see "Technology as IS continuity enabler" subsection in Section 4). As Messer (2009) argues, continuity planning "is not only planning for what to do when an event occurs, but the preparation, planning and implementation to avoid a crisis in the first place" (p. 13). However, monetary constraints often pose significant challenge because advanced technology may require a large budget. Business impact analysis (BIA), as conducted as part of BCP (Pitt & Goyal, 2004), assists organizations to evaluate the value of their technology and choose appropriate measures thereof (Messer, 2009). The estimation is often based on subjective evaluation of the (monetary) value of the technologies the organization uses, which is likely shaped by the organizational social conditions. Even if the organization is able to invest in the latest advanced technologies, there is always a possibility for an incident in an unpredictable, uncertain, and turbulent environment. Plans complement the technologies and prepare organizations for the time when an incident occurs.

The plans should reflect the technology-in-normal-use, but the contents are created by social actors (although the technology/media used to store and create the plans may impose limitations as to how the plans are created and what they contain). The social actors' individual and collective understanding and experience of the technology-in-normal-use, construction of how technology should be improved, and what should be documented because plans are likely to vary and evolve during the preparation process. The BIA, for instance, shapes the social conditions by changing organizational members' view on continuity as business-as-usual (Messer, 2009) that is likely to promote embeddedness (Herbane et al., 2004).

Further, the various social actors that should participate to the planning process (Kendall et al., 2007) are likely to evaluate the most significant threats to organization differently. Using a decision support system to make evaluations is likely to influence the evaluation (Van de Walle & Rutkowski, 2006) and may change how the social actors view the different technologies that make up the organizational technology-in-normal-use. The implemented decision support system, when adopted by the organization, becomes integrated as a part of its technology-in-normal-use. Once the technology is implemented and adopted, it becomes implicated in and shapes the further cycles of preparations (for instance, by shaping the estimations of the severity of imagined incidents). There is, thus, a cyclic relation (depicted in Figure 2 with the blue, curvy arrows) between the technology-in-normal-use and the social conditions as cycles of reflection and improvement.

5.1.2 The Response

An incident induces a shift from preparation to response (indicated by the blue right-pointing arrow on Figure 2). The incident changes the organizational technology-in-normal-use based on the incident's magnitude. However, the degree of change may vary between very insignificant to very significant (or catastrophic). The more entangled the technology is to organizational processes, the more important the IT system likely is and the more severe organizational damage it can be assumed to inflict. Interestingly, technology that fails may very well be the tool that supports the incident preparations and response and may, thus, become a source of an incident itself. In other words, IT tools and the risk of incident they pose *imbricate*: "the powerful digital 'tools' that enable the more sophisticated representation of risks are at the same time the cause of a potential irruption of the 'incalculable', of not easily representable risks due their man-made character arising from insidious, rare, and undetectable side-effects" (Ciborra, 2006, p. 1341).

Incident magnitude influences what response is suitable. Organizations should first and foremost rely on plans (Stucke et al., 2008). While the plans themselves will not provide any response to an incident per se but need attentive social actors to enact them, a plan's comprehensiveness influences whether it can be used as a basis for response. A plan's comprehensiveness also means that it is accurate because false or inaccurate information is of little use; it is imperative to periodically review the plans. A continuity-aware culture is likely to promote keeping the plans up-to-date (King, 2003), which can be achieved by using supportive IT technology (Husband, 2007). However, if the incident falls beyond that which is planned and documented, organizations have to resort to adaptability and social ingenuity. The possibilities for response are further shaped by the technology-in-incident. For instance, whether the organizational normal communication channels, such as email and instant messaging, are available for use alter the ways in which an organization can reorganize itself (e.g., form virtual teams during an incident (Roitz & Jackson, 2006)) and coordinate the response. Thus, responding to a given incident is likely shaped by the interplay of the social conditions, plan comprehensiveness, and the technology-in-incident.

5.1.3 The Outcome

After an incident, organizations should review and revise their plans and their actions and other current measures taken during the incident. Past incidents can be a valuable source for improvement (Lindström et al., 2010b) and help organizations to survive future incidents (Alonso & Boucher, 2001). The actions and measures taken a prior but also during an incident are likely to influence the outcome. Indeed, it would not make much sense to make preparations unless they influenced the outcome when organizations face an incident. Organizations are then to assess whether the preparations and the enacted response to an incident succeeded or failed, which they may do by evaluating success against the pre-calculated RTO/RPO values. Thus, if an organization fails to meet the calculated objectives, the response is a failure, and when the recovery is in the calculated objectives, it is a success. Naturally, if the a posteriori analysis suggests that the experienced incident was too costly for the organization even if the RTO/RPO was met, the past incident provides a point for readjusting the RTO/RPO values to more realistic calculations. That is, the incident becomes a point of learning for the organization.

Even though the main emphasis of the research on salience of IS continuity (see "Salience of IS continuity" subsection) has been on the significance and positive effects of making preparations for incidents, the research extends from the initial organizational (social) conditions to recovery and post incident outcome. The research on the salience of IS continuity fits to the framework through interrelations to two parts of the framework. First, the research on the salience of IS continuity may contribute to organizations' incident preparations by altering the initial social conditions through motivating descriptions and elaborations, communicated to scholars and practitioners through various publication outlets, on why organizations should make a priori preparations. Second, the a posteriori analyses documents the lessons learned from past incidents for wider audience and, thus, serve as important points of reflection to others. Indeed, such research is beneficial to organizations as a knowledge base of what has and has not worked in the past.

5.2 Recommendations for Future Research

Structuring the past has opened venues not yet taken by scholars interested in IS continuity. The discussion and the future directions here should highlight the need for (and, hopefully, attract) new scholarly contributions to IS continuity (and business continuity in general)—both outside and in the IS discipline's confines. The dotted line arrows in Figure 2 indicate research gaps (RG) in the framework. The RGs are not all-encompassing and reflect the current state of IS continuity (i.e., many other gaps likely await discovery as the research on IS continuity progresses). The identified RGs build on the reviewed literature but focus on BC's socio-technical aspects. Focusing on the socio-technical aspects that are interactional is relational to the integrative and interdisciplinary focus of this research: that is, it brings together rather than separates and keeps apart. While this choice might overlook certain (important) gaps that are not relational to the interactional focus, for the sake of community formation around IS continuity, locating and proposing a research agenda that includes interactional areas is likely beneficial. The interactional areas promote collaboration in such a way that scholars from different disciplines may bring their particular strengths and perspectives to address a mutually shared concern and, thus, colligate scholars across disciplines. Table 2 briefly overviews the identified RGs.

Table 2. Research Gaps (RGs)

RGs	Related research	What is known	Description of RG	Possible ways of researching
RG1	Stanton (2005), Kite & Zucca (2007), Seow (2009), Lindström et al. (2010a)	Top management's attitude and social and organizational culture influences organizational willingness to initiate preparations.	The interaction between technology-in-normal-use and initial social conditions.	Empirical research studying how the type and organizational dependency of technology shapes organizational willingness to initiate incident preparations.
RG2	King (2003), Herbane et al. (2004)	Organizational culture and embeddedness promotes planning. Technology aids the creation and maintenance of plans.	The cyclic interaction between social conditions and technology-in-normal-use.	Empirical research studying how the organizational social conditions influence the social construction of the technology and shape the continuity planning and implementation of continuity (enhancing) technology. Empirical research studying how the process of preparations unfold and evolve in practice.
RG3	Kendall et al. (2005), Butler & Gray (2006), Gibb & Buchanan (2006)	In a broad sense, organizations that have prepared for incidents seem to cope better with incidents. Testing and exercising plans and procedures as part of preparations prepare organizations for real incidents. Social conditions may alter organizations' ability to detect early cues to avoid incidents.	The transition of social conditions between preparations and response.	Empirical research studying how the social conditions between preparations and response shift due to the incident conditions and vary under artificial versus real conditions.
RG4	Berman (2002), Halliwell (2008)	Incidents differ in magnitude. Environmental aspects (e.g., day of the week, access to office premises) influence the magnitude. Magnitude influences response, but the response also influences the magnitude (e.g., activities may hide incidents, incidents may cascade, or response may create more damage).	The interaction between "technology-in-incident" and incident magnitude.	Empirical research studying how the type of incident (in contrast to environmental aspects) is related to the magnitude of incident as experienced by an organization. Empirical research studying how the magnitude of similar type of incidents is shaped by the type and use of organizational technology.

Table 2. Research Gaps (RGs)

RGs	Related research	What is known	Description of RG	Possible ways of researching
RG5	Roitz & Jackson (2006), Sapateiro et al. (2011), Heng et al. (2012), Rapaport & Kirschenbaum (2008)	BC plans provide basis for response action. Technological tools designed for responding to incidents improve coordination and collaboration during them. Technology implemented for other purposes, such as telecommuting, may become enacted as tools for incident response. Social relations and individual background influence response.	The interaction between social conditions, plans and technology-in-incident.	Empirical research studying the occurrence and enactment of responses to an incident to understand how the incident response (which likely combines the social conditions (e.g., social relations, mindfulness), plans, and technology) unfolds during an incident as organizational actors individually and collectively respond to it.
RG6	Cervone (2006), Geelen-Baass & Johnstone (2008), Messer (2009)	Organizations that have been able to return to normal business after an incident in the preplanned timeframe are successful.	The transition from response to evaluating success or failure.	Empirical research on how organizational members individually and collectively construct the meaning of success or failure of responding to an incident. Empirical or conceptual research on how success or failure can be measured by alternative metrics.

5.2.1 The Interaction Between Technology-in-Normal-Use and Initial Social Conditions

As Hecht (2002) argue, any organization dependent on IS requires BCM. But how do organizations' understanding of the IS dependency form and what are the individual- and collective-level factors that shape the understanding (RG1)? Organizations are complex, and the technologies they use are many and often interact with each other. Under such conditions, various factors likely shape organizational understanding of the dependency on IS. Prior research focusing on top management support, at least implicitly, acknowledges that the matter is not straightforward. Otherwise, there would be no need to "sell" the BC to top management or to convince them. Technology implementations and already existing technology in use are likely to influence organizational social conditions. For instance, implementing an organizational-wide critical information system will increase an organization's technology dependence and shape how the organization understands its technologies role in relation to organizational BC. However, the relation between technology implementation or technology in use (technology-in-normal-use) to incident preparations should be studied further (RG1, RG2).

5.2.2 The Cyclic Interaction between Social Conditions and Technology-in-Normal-Use

Based on this review, it seems that we know little about the actual process of BC preparations: how the process unfolds and evolves, how the involved actors make sense of the preparations as the process evolves, how their understanding develops, how the actions evolve, and how the social processes and conditions are shaped and reshaped during the process (RG2). Although the prior literature includes accounts of how an implementation has proceeded, they are often descriptive in nature. Instead of straightforward accounts of the implementation, we need studies that convey the complexity and surfaces the meanings and goals (perhaps even conflicting) of the participants.

5.2.3 The Transition of Social Conditions between Preparations and Response

Studies focusing on preparing for an incident largely assume the preparations are, indeed, effective during an incident. However, we lack studies focusing on the transition from normal operating conditions to responding to an incident (i.e., RG3). As organizations integrate more tightly with technology, organizational conditions, both the technological and social, are likely to change abruptly in the awake of an incident. How the actual incident induced shifts in the conditions match a priori expectations of incident conditions has not received the needed attention. Shifts in the conditions may have significance to whether a priori preparations are effective or whether they shatter when an organization truly experience an incident. However, researching such transitions poses difficulties for research due to their relatively rare occurrence and unpredictability (cf. Stallings, 2007), especially as, in an optimal case, the research would have to take place in situ rather than a posteriori for a naturalistic research setting.

5.2.4 The Interaction between Technology-in-Incident and Incident Magnitude

Organizations differ in their technology use and the technological configurations they have are likely to influence the incident magnitude. For instance, robust and highly available technology is more likely to withstand incidents better than other technology as Bajgoric's (2009) “always-on” computing suggests. However, not only the magnitude but also the type of an incident is likely to result in different responses and to differing outcomes (RG4). For instance, technology breakdowns are likely to initiate a different response than a malicious user circumventing a technology's security mechanisms. Understanding how incidents' qualitative differences shape organizations’ experienced magnitude and response to them could potentially contribute not only to more effective responses but also to better explaining the challenges related to preparing for incidents. Understanding the qualitative differences would imply a shift in BC’s underlying assumption to come up with generalized and common processes for preparing for and responding to incidents to appreciate the qualitative differences—the nuances of incidents that matter. Although generic abstractions as methodological steps are certainly indispensable in guiding organizations in their efforts to prepare for and respond to incidents, they largely assume the actual practices of preparations will automatically follow as soon as appropriate and accurate abstractions have been grasped. However, we can expect that, on the micro-level, in the level of actual practices, preparing IS for natural disasters differs from preparing them for man-made ones.

5.2.5 The Interaction between Social Conditions, Plans and Technology-in-Incident

The role of plans, technology, and social conditions during an incident is largely unsolved in IS continuity literature. To understand how plans are actually effective and used during adverse conditions would improve understanding on the matter. Wider IS literature suggests plans, under normal conditions, are not enacted in practice but rather act as an information source (Suchman, 2005). If such is true also with incidents, how plans are used will likely differ from the BC planners’ intended use. Thus, understanding how plans are enacted under real conditions may provide useful insights for preparing effective plans. Further, technologies’ flexibility and availability during an incident likely shape organizational actions. Such situations are likely to require increased use of different technologies (e.g., diagnostics and troubleshooting technology), well-thought-out pre-planned actions, and social conditions that facilitate ingenuity. How technology, plans, and social actions interconnect during an incident response also requires more attention (RG5).

5.2.6 The Transition from Response to Evaluation of Success or Failure

Knowing when organizational BC is a success or a failure is difficult to assess. The above integrating framework suggests one possible way to assess success or failure is to use the calculated RTO / RPO values. However, these values are calculated as the last point of recovery; that is, as the last possible point from which the recovery is still possible before the organization suffers so much damage that it will very likely perish. However, organizations are likely to benefit from other measures of success / failure than assessing whether it (as a whole) survives from the incident or not. Further, success / failure is likely to be a more complicated construct. Any preparations and response to incidents will likely have certain factors/aspects that have been successful and factors/aspects that have been a failure. Therefore, future research should find ways to assess the success or failure of BC (RG6) in more detail.

5.3 Limitations

This research is subject to limitations. First, it focuses on peer-reviewed journal papers instead of wider practitioner and conference literature. Business continuity is practitioner driven, and many papers in professional publication outlets are likely to also cover some aspects of interest for scholars interested in IS continuity. Thus, the literature review provided here might not present a complete picture of the topic. Nevertheless, the literature review provides a useful reference source for both the practitioners and academics. In addition, the review approach I use is subjective to some degree. I did not cover all papers in the review to the same extent. Instead, I chose to elaborate on papers I deemed as influential, illustrative, or interesting. Needless to say, resulting from the selection process, some authors' voices are more visible than others'. Categorization summaries and quantifications of the reviewed papers balance the limitation to some extent, but do not fully remove it.

6 Conclusion

In this paper, I review the multidisciplinary literature on business continuity (BC) from an IS perspective. The review was guided by the question: “how organizations can prepare for and respond to IS incidents?”. The reviewed literature forms the foundations of IS continuity.

Following Webster and Watson (2002), I thematized the past contributions on IS continuity. To this end, four main themes emerged from the literature: (1) social aspects as IS continuity enabler, (2) technology as IS continuity enabler, (3) salience of IS continuity, and (4) models that improve IS continuity. I also suggest an integrative framework by building on and extending the reviewed literature to progress discussion around BC toward a unified view of IS continuity, and, further, to pinpoint research gaps. The integrative framework promotes a view of BC in which plans, technologies, and social aspects complement and interact with each other.

This research contributes to the literature on BC by structuring the past contributions and identifying possible paths for future research, especially for those interested on the part that IS has for business continuity. At best, interdisciplinary projects such as this one encourage a community’s formation (Stember, 1991). This research contributes to forming a community around IS continuity, which is a shared topic of interest among scholars across disciplines. Further, as Klein and Hirscheim (2008) argue, one can characterize IS as a diverse set of practice communities and knowing among which “[w]e need to choose our particular communities and fully engage with them” (Walsham 2012, p. 3). To this extent, by identifying and structuring the literature under the IS continuity concept, this research enables scholars to identify this particular community of practice and knowing. While this research cannot guarantee that a prosperous and vivid community will evolve around the IS continuity, it will hopefully lower the barrier of joining the already existing, although fragmented, community.

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Appendix A: Title of the Appendix

Categorization of journals to IS discipline followed that of Siponen and Willison (2007) with some additions; Communications of the ACM, Computer Fraud & Security, IT Pro, IT Now, Network Security, Information Systems Frontier, Review of Business Information Systems and Campus-Wide Information Systems were included as IS journals (see Table A1). Categorization of non-IS journals to disciplines is based on the journals own assessment. For instance, the American Journal of Economics and Business Administration was categorized to 'economics' discipline as it "publishes original, innovative and novel work in various areas representing the intersection of economics as a scientific discipline and the professional practice of business management" (Science Publications, 2014). Journals that target multiple disciplines are categorized as "multidisciplinary".

Table A1. List of Journals

IS (27 papers / 32,5%)	**Non-IS (56 papers / 67,5%)**
Campus-Wide Information Systems (1 / 1,2%)	*American Journal of Economics and Business Administration* (2 / 2,4%) (Economics)
Communications of the ACM (1 / 1,2%)	*American Water Works Association* (1 / 1,2%) (Multidisciplinary)
Communications of the Association for Information Systems (2 / 1,2%)	*Asian Social Science* (1 / 1,2%) (Multidisciplinary)
Computers & Security (1 / 1,2%)	*ASBM Journal of Management* (1 / 1,2%) (Management)
Computer Fraud & Security (4 / 4,8%)	*Australian Health Review* (1 / 1,2%) (Health care)
Decision Support Systems (1 / 1,2%)	*Bell Labs Technical Journal* (2 / 2,4%) (Multidisciplinary)
Information Management & Computer Security (3 / 3,6%)	*CPA Journal* (1 / 1,2%) (Multidisciplinary)
Information Systems Frontier (1 / 1,2%)	*Disaster Prevention & Management* (4 / 4,8%) (Multidisciplinary)
Information Systems Management (1 / 1,2%)	*Facilities* (1 /1,2%) (Multidisciplinary)
Information Security Journal: A Global Perspective (formerly *Information Systems Security*) (2 / 2,4%)	*IBM Systems Journal* (1 / 1,2%) (Information science)
International Journal of Information Management (1 / 1,2%)	*Industrial Management & Data Systems* (1 / 1,2%) (Multidisciplinary)
IT Now (2 / 2,4%)	*International Journal of Business Continuity and Risk Management* (2 / 2.4%) (Multidisciplinary)
IT Pro (1 / 1,2%)	*International Journal of Business and Social Science* (1 / 1,2%) (Multidisciplinary)
Network Security (5 / 6%)	*International Journal of Emergency Management* (1 / 1,2%) (Multidisciplinary
	International Journal of Information Systems for Crisis Response and Management (1 / 1,2%) (Crisis management)
	Internal Auditor (1 / 1,2%) (Internal auditing)
	Journal of Business Continuity & Emergency Planning (22 / 26,5%) (Multidisciplinary)
	Journal of Facilities Management (1 / 1,2%) (Facilities management)
	Journal of GXP Compliance (1 / 1,2%) (Multidisciplinary)
	Journal of Homeland Security and Emergency Management (2 / 2,4%) (Multidisciplinary)
	Journal of Organizational Excellence (1 / 1,2%) (Multidisciplinary)
	Journal of Universal Computer Science (1 / 1,2%) (Computer science)

Table A1. List of Journals

IS (27 papers / 32,5%)	Non-IS (56 papers / 67,5%)
	Long Range Planning (1 / 1,2%) (Strategic management)
	Management Quarterly (1 / 1,2%) (Management)
	OCLC Systems & Services (1 / 1,2%) (Multidisciplinary)
	Risk Management: An International Journal (2 / 2,4%) (Multidisciplinary)
	Work Study (1 / 1,2%) (Multidisciplinary)

Appendix B: Research Approaches and Thematized Contributions

Table B1. Summary of Research Approaches and Themes

Theme	Author(s)	Year	Cases	Concept	Exp.	Interv.	Survey
Models	Iyer & Bandyopadhyay	2000		√			
	Nosworthy	2000		√			
	Lam	2002		√			
	Savage	2002		√			
	Smith	2003		√			
	Swartz et al.	2003	√				
	Botha & von Solms	2004		√			
	Cerullo & Cerullo	2004		√			
	Jrad et al.	2004		√			
	Shaw & Harrald	2004		√			
	Castillo	2005	√				
	Kendall et al.	2005		√			
	Cervone	2006	√				
	Gibb & Buchanan	2006		√			
	Power & Forte	2006		√			
	Alesi	2008	√				
	Dye	2008	√				
	Freestone & Lee	2008	√				
	Geelen-Baass & Johnstone	2008	√				
	Halliwell	2008	√				
	Sheth, McHugh, & Jones	2008		√			
	Thornton	2008	√				
	Turetken	2008		√			
	Vaid	2008		√			
	Alonaizan	2009	√				
	Devlen	2009		√			
	McLouglin	2009	√				
	Nollau	2009		√			
	Paton	2009		√			
	Wan	2009	√				
	Arduini & Morabito	2010		√			

Table B1. Summary of Research Approaches and Themes

Theme	Author(s)	Year	Cases	Concept	Exp.	Interv.	Survey
	Lindström et al.	2010a	√				
	Lindström et al.	2010b		√			
	Shaw & Smith	2010		√			
	Tammineedi	2010		√			
	Karim	2011					√
	Järveläinen	2012				√	
	Moyer & Novick	2012		√			
	Sum	**38**	**13**	**23**	**0**	**1**	**1**
Salience	Alonso & Boucher	2001		√			
	Berman	2002	√				
	Hecht	2002	√				
	Herbane et al.	2004	√				
	Ernest-Jones	2005	√				
	Hinde	2005		√			
	Stanton	2005		√			
	Brettle	2006		√			
	Walker	2006	√				
	Windsor	2006		√			
	Messer	2009		√			
	Kite & Zucca	2007		√			
	Hunter	2008		√			
	Low et al.	2010					√
	Momami	2010		√			
	Pheng et al.	2010					√
	Streufert	2010	√				
	Baker	2012		√			
	Sum	**18**	**6**	**10**	**0**	**0**	**2**
Social	King	2003		√			
	Pitt & Goyal	2004					√
	Butler & Gray	2006		√			
	Shaw & Harrald	2006					√
	Rapaport & Kirschenbaum	2008					√
	Walch & Merante	2008		√			
	Seow	2009		√			
	Wong	2009		√			
	Sawalha & Anchor	2012		√			
	Sawalha et al.	2012		√			
	Sawalha & Meaton	2012		√			
	Sum	**11**	**0**	**8**	**0**	**0**	**3**
Technology	Ionescu	2002		√			
	Bertrand	2005		√			
	Bajgoric	2006		√			

Table B1. Summary of Research Approaches and Themes

Theme	Author(s)	Year	Cases	Concept	Exp.	Interv.	Survey
	Roitz & Jackson	2006	√				
	van de Walle & Rutkowski	2006			√		
	Husband, R.	2007	√				
	Coullahan & Shepherd	2008		√			
	Lumpp et al.	2008		√			
	Bajgoric & Moon	2009		√			
	De Luzuriaga	2009	√				
	Bajgoric	2010		√			
	Asgary & Mousavi-Jahromi	2011					√
	Sapateiro et al.	2011				√	
	Bajgoric, N.	2012		√			
	Ceballos et al.	2012		√			
	Heng et al.	2012	√				
	Sum	**16**	**4**	**9**	**1**	**1**	**1**
Total		**83**	**23**	**51**	**1**	**2**	**7**

Appendix C: References of IS Continuity Papers

Table C1. List of Reviewed IS Continuity Papers

A-G	H-O	P-Z
Alesi, P. (2008). Building enterprise-wide resilience by integrating business continuity capability into day-to-day business culture and technology. *Journal of Business Continuity & Emergency Planning*, *2*(3), 214-220. Alonaizan, A. (2009). Developing a business continuity programme at Arab National Bank. *Journal of Business Continuity & Emergency Planning*, *3*(3), 216-221. Alonso, F., & Boucher, J. (2001). Business continuity plans for disaster response. *The CPA Journal, 71*(11), 60. Arduini, F., & Morabito, V. (2010). Business continuity and the banking industry. *Communications of the ACM*, *53*(3), 121-125. Asgary, A., & Mousavi-Jahromi, Y. (2011). Power outage, Business Continuity and Businesses' Choices of Power Outage Mitigation Measures. *American Journal of Economics and Business Administration*, *3*(2), 312-320.	Halliwell, P. (2008). How to distinguish between" business as usual" and "significant business disruptions" and plan accordingly. *Journal of Business Continuity & Emergency Planning*, *2*(2), 118-127. Hecht, J. A. (2002). Business continuity management. *Communications of the Association for Information Systems*, *8*, 444-450. Heng, T., Hooi, S., Liang, Y., Othma, A., & San, O. (2012). Telecommuting for Business Continuity in a Non-profit Environment. *Asian Social Science*, *8*(12), 226-237. Herbane, B., Elliott, D., & Swartz, E. M. (2004). Business continuity management: Time for a strategic role?. *Long Range Planning*, *37*(5), 435-457. Hinde, S. (2005). From incidents to disasters. *Computer Fraud & Security*, *2005*(4), 17-19. Hunter, P. (2008). Eastern Internet outage brings customary boom in business continuity. *Computer Fraud*	Paton, D. (2009). Business continuity during and after disaster: Building resilience through continuity planning and management. *ASBM Journal of Management*, *2*(2), 1-16. Pheng, L. S., Ying, L. J., & Kumaraswamy, M. (2010). Institutional compliance framework and business continuity management in mainland China, Hong Kong SAR and Singapore. *Disaster Prevention and Management*, *19*(5), 596-614. Pitt, M., & Goyal, S. (2004). Business continuity planning as a facilities management tool. *Facilities*, *22*(3/4), 87-99. Power, R., & Forte, D. (2006). You don't need a weatherman to know which way the wind blows: business continuity in the 21st century. *Computer Fraud & Security*, *2006*(8), 17-19. Rapaport, C., & Kirschenbaum, A. (2008). Business continuity as an adaptive social process. *International Journal of Emergency Management*,

Table C1. List of Reviewed IS Continuity Papers

A-G	H-O	P-Z
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Table C1. List of Reviewed IS Continuity Papers

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Coullahan, R. J., & Shepherd, C. D. (2008). Enhancing enterprise resilience in the commercial facilities sector. *Journal of Business Continuity & Emergency Planning*, *3*(1), 5-18.	Low, S., Liu, J., & Sio, S. (2010). Business continuity management in large construction companies in Singapore. *Disaster Prevention and Management*, *19*(2), 219-232.	Stanton, R. (2005). Beyond disaster recovery: the benefits of business continuity. *Computer Fraud & Security*, *2005*(7), 18-19.
De Luzuriaga, J. (2009). Ensuring business continuity for business process outsourcing companies. *Journal of Business Continuity & Emergency Planning*, *3*(4), 312-316.	Lumpp, Th., Schneider, J., Holtz, J., Mueller, M., Lenz, N., Biazetti, A., & Petersen, D. (2008). From high availability and disaster recovery to business continuity solutions. *IBM Systems Journal, 47*(4), 605-619.	Streufert, J. (2010). Business continuity strategies for cyber defence: Battling time and information overload. *Journal of Business Continuity & Emergency Planning, 4*(4), 303-316.
Devlen, A. (2009). How to build a comprehensive business continuity programme for a healthcare organisation. *Journal of Business Continuity & Emergency Planning*, *4*(1), 47-61.	McLoughlin, R. (2009). What one must know about achieving BS25999-2 certification. *Journal of Business Continuity & Emergency Planning*, *3*(2), 105-111.	Strong, B. (2010). Creating meaningful business continuity management program metrics. *Journal of Business Continuity & Emergency Planning, 4*(4), 360-367.
Dye, K., & Langsett, M. (2008). A roadmap to measure and achieve enterprise operational resiliency, *Journal of Business Continuity & Emergency Planning*, *3*(1), 38-46.	Messer, I. (2009). Taking the business continuity programme to a corporate leadership role. *Journal of Business Continuity & Emergency Planning*, *4*(1), 8-13.	Swartz, E., Elliott, D., & Herbane, B. (2003). Greater than the sum of its parts: Business continuity management in the UK finance Sector. *Risk Management*, *5*(1), 65-80.
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Geelen-Baass, B. N., & Johnstone, J. M. (2008). Building resiliency: ensuring business continuity is on the health care agenda. *Australian Health Review*, *32*(1), 161-173.	Nollau, B. (2009). Disaster recovery and business continuity. *Journal of GXP Compliance*, *13*(3), 51-58.	Turetken, O. (2008). Is your back-up IT infrastructure in a safe location?: A multi-criteria approach to location analysis for business continuity facilities. *Information Systems*
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Table C1. List of Reviewed IS Continuity Papers

A-G	H-O	P-Z
141.	Nosworthy, J. (2000). A practical risk analysis approach: managing BCM risk. *Computers & Security*, *19*(7), 596-614.	*Frontier, 10*(3), 375-383. Vaid, R. (2008). How are operational risk and business continuity coming together as a common risk management spectrum? *Journal of Business Continuity & Emergency Planning*, *2*(4), 330-339. Van de Walle, B., & Rutkowski, A. (2006). A fuzzy decision support system for IT service continuity threat assessment. *Decision support systems*, *42*(3), 1931-1943. Walch, D., & Merante, J. (2008). What is the appropriate business continuity management staff size? *Journal of Business Continuity & Emergency Planning*, *2*(2), 240-250. Walker, A. (2006). Business continuity and outsourcing—moves to take out the risk. *Network Security*, *2006*(5), 15-17. Wan, S. (2009). Service impact analysis using business continuity planning processes. *Campus-Wide Information Systems*, *26*(1), 20-42. Windsor, C. (2006). Business Continuity—is it expensive and hard?. *IT Now, 48*(2), 12-13. Wong, W. N. Z. (2009). The strategic skills of business continuity managers: Putting business continuity management into corporate long-term planning. *Journal of Business Continuity & Emergency Planning*, *4*(1), 62-68.

About the Authors

Marko Niemimaa is a PhD candidate at the Turku Centre for Computer Sciences and University of Turku, Turku School of Economics in the department of Information Systems. He has started his PhD in 2010 and his main research interests lie in the discipline of IS security where he mainly focuses on business continuity and information security management. His publications have appeared in (IS) journals and (IS) conferences, such as International Journal of Social and Organizational Dynamics in IT (IJSODIT), International Journal of Information Systems for Crisis Response and Management (IJISCRAM), Hawaii International Conference on Systems Sciences (HICSS), and International Conference on Availability, Reliability and Security (ARES). He holds an MSc degree in information security and a BBA degree in business information systems. Prior to joining the academia, Marko has worked nearly 10 years in the industry as an information security professional and consultant. During those years he successfully led a team of technical information security professionals and managed various customer projects around the globe in developing and developed countries.

Article #2: Niemimaa, M. (2015). “Extending ‘toolbox’ of business continuity approaches: Towards practicing continuity”, in *Proceedings of the Americas Conference on Information Systems (AMCIS)*, Puerto Rico, US: Association for Information Systems, pp. 1-11.

2.

Extending 'Toolbox' of Business Continuity Approaches: Towards Practicing Continuity

Full Paper

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Abstract

As incidents may have devastating effects for organizations' value creation, preparing for incidents is imperative regardless of organization or the market context. Scholars interested in business continuity have studied ways in which organizations may prepare for the unexpected, and, when realized, respond effectively. Three approaches to continuity are particularly visible in the literature: (1) plans for continuity; (2) technologies for continuity; and (3) social ingenuity for continuity. In addition, a fourth approach has been emerging that underlines the importance of work practices for business continuity. In this research, the fourth approach, 'practicing continuity', is extended and developed further as part of the existing 'toolbox' of business continuity approaches. The fourth perspective, in contrast to the three other approaches, is found especially fruitful as it focuses on the constitutive interaction of social and material aspects of work. Implications for business continuity are discussed and conclusions drawn.

Keywords

business continuity, continuity planning, incident preparations, practice theory, sociomaterial

Introduction

An organization's ability to sustain the continuity of its Information Systems (IS) and operations is imperative for value creation. Whether operating in the densely populated and highly competitive 'red ocean' or in the fresh, unpopulated and competitor-free 'blue ocean' (Kim & Mauborgne, 2004), befalling events may disrupt the organization's operations and have devastating consequences. That is, while organizations' strategies may differ in important ways, once they have secured a competitive position in the markets, sustaining that position becomes crucial (Ibid.). However, incidents, in any case, when not successfully anticipated and coped with 'threaten the strategic goals of organisations' (Richardson, 1994, p.63). An organizations' ability to continue operations is thus a precondition for the realization of organization's long term goals, and, likewise, a threat to the organization's strategic advantage 'threatens the continuity of operations over a prolonged period' (Herbane et al., 2004, p.439). Since such incidents are likely to prevent organizations from enacting their strategies, complacency is not an option.

In a path paved by practitioners (Zsidisin et al., 2005), scholars interested in business continuity (the shorter form 'continuity' is used interchangeably) have focused on understanding and improving the preparations for and responses to all types of (harmful) incidents for decades (Herbane, 2010). Because incidents come in many shapes and forms, and may even exhibit idiosyncratic patterns, a common assumption shared by scholars studying business continuity is that certain forms of organizing are likely to be more effective than others to prepare for and confront harmful events. During over 40 years of evolution, the scope of business continuity has evolved from an IT-centric view that emphasized preparing plans for IT system recovery, into a broader organizational scope (Herbane, 2010). The broadened scope meant that the IT system was not the core of the preparations anymore but the organizational functions consisting of complex amalgams of humans, technologies and material 'things' that enable the performance of those functions. However, while a consensus on the scope seems to exist amongst scholars and practitioners alike, it seems to exist to lesser degree in relation to how to understand and improve the business continuity.

Three approaches to continuity seem to be particularly apparent in the literature and are referred to here as (1) plans for continuity; (2) technologies for continuity; and (3) social ingenuity for continuity. The first approach takes the view that continuity is first and foremost a planning problem improvable by plans; the second takes the view that continuity is a technological problem improvable by more (advanced) technology; and the third holds that continuity is relational to social and cognitive factors of human actors. As such, research across these approaches draws theoretical insights and practical solutions from differing, and perhaps even incongruent, knowledge bases. For example, where some are more likely to delve into the theories of computer sciences and look for advanced technological solutions to find optimal improvements (e.g., Bajgoric (2006)), others turn to social and cognitive theories to look for ways in which the social ingenuity can be enhanced and more effective cognition achieved (e.g., Butler and Gray (2006)). More elaborate discussion of the approaches will be provided below.

In addition to the three aforementioned approaches, a fourth approach has been emerging that has been explicitly addressed by some, and more or less implicitly by few others, but that has remained underdeveloped. The fourth approach, *practicing continuity*, takes the view that in order to improve and understand continuity it is necessary to improve and understand employees' work practices and routines they enact while working. That is, the central premise is that business continuity arises from what work is done and how is it performed (cf. Butler and Gray (2006)) rather than from any one specific aspect of organizational work. The purpose of this conceptual study is to explore and develop (theoretically/conceptually) this particular approach further. Focusing on the fourth perspective was deemed significant not only because of its immaturity but because it seems an insightful and fruitful way forward – practices are the nexus of people, technologies and 'things' (Schatzki et al., 2001). That is, practices have both material *and* social dimensions. (Barad, 2007; Orlikowski & Scott, 2008). It should be noted at the outset that it is not the intention of this research to argue for the superiority of this one specific continuity approach but to develop and extend the existing 'toolbox' of continuity approaches further.

The rest of the article proceeds as follows. First, the three prevailing approaches to continuity are introduced successively and some weaknesses in each approach are pointed out. Second, the practicing continuity approach is conceptually developed further to extend the current understanding. Lastly, the contributions of the practicing continuity approach to business continuity are discussed and conclusions are drawn.

Prevailing Approaches to Business continuity

During the course of this chapter, three approaches to understanding and improving continuity are introduced. While the discussions have been multidisciplinary in general, the topic has been one of the central items on many IS security and IS operations scholars' agendas (Siponen & Willison, 2007; Butler & Gray, 2006). The following discussion starts by outlining the continuity plans approach, proceeds with continuity technologies and ends with social ingenuity. As plans, and the related planning methodologies, have been central to the development of business continuity (Herbane, 2010), slightly more space is reserved for them.

Plans for Continuity

Continuity plans have been traditionally viewed as the core of organizational preparations to incidents (Stucke et al., 2008; Herbane, 2010). The plans, optimally, provide prescriptive steps that govern an organization's recovery activities to ensure smooth and prompt recovery after an incident. Initially the plans were specific to an IT system and provided basis for its recovery activities (Herbane, 2010). In practice, they documented the procedural instructions to reinstall an IT system from scratch in order to hasten and ease the task of recovery. The task was relatively straightforward, and easily testable. All that was needed was to install the system, document the procedures, and to afterward reinstall the IT system to verify whether the documented procedure matched the steps required in practice. Thus past experience of installing the IT system could be extrapolated and documented as the procedure for future action in the event that the system would have to be recovered. For instance, if a hard drive would break down, even a novice IT system administrator could follow the documented procedure for successful recovery. However, often, IT systems seemed to have a will of their own, and despite the relatively straightforward procedure things would not go as documented and would require a degree of *in situ* adjustment. Nevertheless, the plans persisted as a useful way to prepare the organizations for the uncertain future.

While this type of IT recovery plan is still a part of many business continuity plans, the focus has shifted from reactive and passive awaiting of IT system incidents to proactive assessment of incidents at organizational levels. This also implied a shift in scope from preparing for relatively concrete IT breakdowns to all types of organizational discontinuities. Simultaneously, the plans documenting concrete procedures for reinstalling IT systems widened and became what they are today: a complex set of plans for restoring organizational functions by accounting for the tight coupling of IT and organizations. At the core, however, remained the idea of prescriptive plans.

The content of continuity plans should *ideally* cover all possible discontinuities, and not merely the recovery activities but also prevention activities; all events should be anticipated, and none should befall. As Stucke et al. (2008) argued 'organizations should depend on their well-tested plans for recovery and not on ingenuity' (p. 160). Thus, '[i]n this kind of tidy and objectified world improvising is the last thing analysts want to see happening' (Ciborra, 1999, p.87). Any non-preplanned and non-prescriptive action thus marks, at least partial, deficiency in the plans. However, the ideal goal of being prepared for everything is not meant as a sort of naive claim that proponents of planning approach would realistically expect the ideal goal to be fully achievable. Rather, it represents a goal somewhere in the horizon towards which continuity planners seek to move.

To assist in the complex task of preparing the plans, scholars and practitioners alike have introduced various methodologies and models (e.g., Botha and von Solms (2004); Cerullo and Cerullo (2004); Savage (2002) Post and Diltz (1986)). Here, the methodologies and models refer broadly to the type of abstracted steps organizations should take in order to prepare comprehensive and meticulous plans. The aim is to find the optimal steps – or a subset of steps – for the preparation of the plans. The steps, sometimes referred to as 'best practices', such as the international standards, provide abstracted and context independent guidance on planning (Siponen & Willison, 2009). When planning, deviations from the methodologies are seen as likely explanations of impoverished plans and their failure to meet the demands of emerging discontinuity situations.

While each continuity planning methodology is likely to have its nuances, according to Pitt and Goyal (2004) they commonly share six steps (although the naming conventions may vary): (1) project initiation; (2) risk assessment/business impact analysis; (3) design and development of the plans; (4) creation of the plans; (5) testing and exercising; and (6) maintenance and updating (p. 88)[1]. In short, the purpose of the steps is to come up with conjectural knowledge of the unknown future that is documented as the continuity plans. The planning itself is seen as largely an isolated and separate activity from 'actual' organizational work. Only at the end of the process of planning, the preventive mechanisms of the plan are implemented and then tested. The preventive mechanisms may take any form from prescriptive procedure (cf. IT recovery above) to improvements in technology, such as the configuration or improvement of IT system backup (Botha & von Solms, 2004).

As the research has focused on the plans and abstracting universal steps for creating plans, it has tended to assume that the actual organizational work practices follow in a rather linear fashion. In other words, 'the details of practice have come to be seen as nonessential, unimportant, and easily developed once the relevant abstractions have been grasped' (Brown & Duguid, 1991, p.40). While any guidance on the creation of plans is likely to be beneficial for practitioners who need to design and implement the plans, it is likely that the adoption of any methodology or model into organizational practices is neither linear nor simple. Indeed, quoting Ciborra (1999), '[p]rocedure and method are just 'dead objects': they get situated in the flow of organizational life only thanks to a melange of human motives and actions' (p. 86). Further, recently Larsen et al. (2012) argued that the adoption of software development methodologies and models proceeds through eight different adoption paths in order to transform from abstractions to organizational practices. Although software development methodologies and models are not the same as continuity planning methodologies and models, the authors' findings may also hold true for business continuity.

[1] Due to space constraints, readers are asked to see the details of each step from Pitt and Goyal (2004)

Lastly, as the focus is on plans, the approach pays little attention to the ways in which those plans themselves become implicated into work; plans that are not used (or usable) have very little intrinsic value.

Technologies for Continuity

Technologies (especially IT) have formed the core of one of the approaches to business continuity. For the proponents of the approach 'IT is recognized as an enabler for continuity' (Bajgoric, 2006, p.450). However, technologies have had two roles – sometimes overlapping – as either technologies that improve the reliability and availability of an organization's technological infrastructure or as technologies that are supportive of an organization's business continuity activities.

In relation to the first role of technology, advanced technologies have been found useful to improve the reliability of technological components embedded in organizational information infrastructures and thus to increase the continuity of those infrastructures and, consequently, the organizational functions they support. For the proponents of technologies, the uncertainty and unreliability of technology is resolvable by implementing more technology that represents later developments in the technological race. In other words, every current technology is merely a penultimate, impoverished technology awaiting for replacement by next generations of technologies. Computer architecture based on 32-bit architecture becomes a source of possible discontinuity, while the next generation 64-bit architecture narrows the gap to reach 'always on computing' (Bajgoric, 2006). Similarly, the improvement may complement imperfections in other technological infrastructures such as can be achieved by the installment of Universal Power Supply (UPS) to complement unreliable power infrastructures (Asgary & Mousavi-Jahromi, 2011). That is, in general, these technological improvements are seen as a way to proactively deter, or optimally to prevent altogether, the occurrence of incidents. However, focusing on technologies as proactive measures tells little of what takes place and what should take place when they fail.

In relation to the second role of technology, they are viewed as supportive for organizational activities in preparing for incidents as well as supporting the actual recovery activities. For instance, Van de Walle and Rutkowski (2006), introduced a technology not to improve organization's technological infrastructure but to improve decision making in continuity related probability assessments. More specifically their technology improves quantifications of incident likelihood and impact in such a way that each user may do their estimations in isolation and then have the average score as the basis for discussion and decision making. Scholars have also recognized the importance of technologies during an incident. Such is the case, for instance, in Sapateiro et al. (2011), who developed a mobile software application designed solely for communications and coordination during an incident. Furthermore, as Sakurai and Kokuryo (2014) suggest, the design of technologies may influence organizational and societal restorations. Especially complex technologies may effectively hinder recovery activities that could be averted with a frugal IS design (Ibid.).

As a summary, what this discussion suggests, is a strong belief in technology that is viewed in a deterministic sense (Leonardi & Barley, 2008) – technologies themselves improve continuity rather than their use. Focusing on the technologies largely fails to recognize that whether and how technologies affect organizing 'depends on how the technology is designed, the way it is deployed, and how it is used and interpreted in a specific organizational context' (Barley & Kunda, 2001, p. 79. That is, the technologies overshadow much of the social aspects of organizing.

Social Ingenuity for Continuity

In a rather stark contrast to advocates of technologies or plans, some scholars approach continuity as a social concern. This approach underlines the salience of individual and organizational social aspects to confront and cope with incidents in lieu of solution 'artifacts' – whether technologies or plans. Central to this approach is that not all events can be probabilistically anticipated and planned/prepared for (Butler & Gray, 2006), but require attentive social actors (see also Rapaport and Kirschenbaum (2008)). Therefore, facilitating effective social and cognitive conditions for human actors forms the core of the research around this approach.

Social ingenuity refers broadly to the individual and group level behavior (and the antecedents of that behavior) that has an impact on the preparedness and response to incidents. While some have focused on suggesting social factors that influence the success of, especially, preparedness for incidents, others have focused on explaining how certain cognitive or social processes contribute to continuity. Scholars have found that, for instance, the competencies and size of continuity management staff (Walch & Merante, 2008; Shaw & Harrald, 2006) and organizational and societal culture influence the preparations for incidents (King, 2003; Sawalha & Anchor, 2012: Sawalha & Meaton, 2012). Butler and Gray (2006) viewed continuity through the lens of *mindfulness*, arguing that 'correct' situated human cognition may explain reliable performance of inherently unreliable technology (see also Braun and Martz (2007) for hypothesized relations between mindfulness and continuity planning). Further, the authors argued that while planning techniques 'may increase an organization's ability to perform reliably, the impact of these techniques is affected by the degree to which they either enhance (mediation) or are enhanced by (moderation) collective mindfulness [situated and active cognition]' (p. 218). In addition, social ingenuity may be taken as an extension that is called upon when the plans fail to provide sufficient basis for prescriptive, plan governed/guided action (cf. Berman (2002)). However, such a view provides little understanding as to 'why does planning tend to be obtrusive, stand in the way, be exposed to breakdowns, while improvisation is called upon to come to the rescue in those very situations where plans and procedures typically fail?' (Ciborra, 1999, p.87).

Improving, rather than explaining, social ingenuity has received more modest attention. While the importance of employee awareness has received significant attention amongst IS security scholars interested in information security management and policies (Lebek et al., 2013), scholars interested in business continuity have shown less interest. Despite the fact that there are certainly overlapping and interacting domains between information security and business continuity[2], the type of awareness required in both is likely to qualitative differ. Morwood (1998) suggests organizations should implement awareness and training programmes to ensure that the implemented plans are known by the employees; 'a plan is only as good as your ability to implement it – and your ability to implement it will be highly dependent upon how well your staff members know the BC [business continuity] plan and can execute its tasks'(p. 28). Additionally, incident exercises and testing preplanned procedures are ways of facilitating improvements in the human actors' behavior. Employees who have been rehearsing to confront various incidents are expected to perform better when an actual incident occurs (Kendall et al., 2005).

As indicated above, three ways of approaching continuity seem to prevail. The purpose of the above discussion is not to pinpoint certain scholars or to evoke opposition between them but to surface a broader contention and tension between the approaches. It is likely that any attempt to narrow and bring the approaches closer is beneficial and welcomed by others. As will be discussed next, focusing on practicing continuity may positively contribute to mitigating this contention.

Towards Practicing Continuity

After introducing the prevailing ways to understand and improve business continuity in previous chapter, it is now possible to move towards the fourth, emerging approach. In contrast to research focusing on understanding and improving continuity through plans, technologies or social aspects, the fourth approach underlines their constitutive interaction in practice. That is, to understand continuity is to understand how the plans, technologies, human actors and other 'things' combine in and form work practices, and, consequently, to improve continuity is to transform ways in which people work. In other words, the focus is in the interaction of humans and material things in practice. Quoting Carlile et al. (2013) 'practices are not merely constellations of intersubjectivity, they are also constellations of "interobjectivity"'(quotation marks theirs) (p. 7).

Central for the emerging approach is the recognition that organizational practices and routines shape business continuity outcomes. As the preliminary empirical findings from Herbane et al. (2004) suggest, continuity can be viewed as 'a mix of routines and skills that is observable but not necessarily tangible or transferable' (p. 437). What the authors mean is not that business continuity should be viewed as a set of separate and isolated routines, but on the contrary – it should be viewed as 'an integral and ongoing part of daily routines' (Herbane et al., 2004, p. 447). What this implies is not that all work would be related to

[2] Indeed, the widely used information security management standard, ISO-27001, from International Organization for Standardization (2006) includes a part that also covers business continuity.

business continuity, neither that organizational routines and practices would include a part that is only relevant in respect to business continuity, but that there are certain ways of working that are 'better' than others. As Barley and Kunda (2001) argues, '[h]uman action generates organizational variance' (p. 79). To understand continuity, then, is to understand work and its constituents.

Organizational work happens at the nexus of humans, technologies and 'things' (Schatzki, 2006). Consequently, in order for the work to happen both social and material 'components' – that is combinations of the humans, technologies and things – are needed. However, same or at least closely similar work outcomes can be produced with different social and material configurations of work. For instance, if an accountant needs to calculate company's profits, he or she may do so with paper and pen, with a calculator, or with a computer running a calculator (just to give a few possible options). While it is possible to produce the same outcome with all the options, the outcome is dependent on the joint possibilities formed by the human actor (the accountant) and the material technologies (the paper/pen, calculator, and computer). Whether the outcome will be a correct calculation is not dependent solely on the accountant, neither on the material artifact, but on their *interaction*; paper and pen can produce the correct calculations only in interaction with an actor capable of doing manual calculations and so forth. While social ingenuity is indispensable in findings ways in which the technologies might be used, the ingenuity is always conditioned by the prevailing material conditions. And while technologies are indispensable in extending possibilities of work, they need to be implicated in the organizational work to produce organizational outcomes. Importantly then, the capabilities of technologies and the human actor are neither universals nor are they fixed or possessed by any single component part of a practice, but become determined in certain practices and in relation to one another (Barad, 2007) – in the act of practicing. It is also this ongoing flow of practices, the performance of everyday work that gives rise to and engenders continuity. And it is incidents that actualize as the abrupt transformations or disruptions of this ongoing flow.

The transformation or disruption of the ongoing flow of practices is often contingent on the material aspects of work. As practices are constitutive configurations of social and material components (Orlikowski & Scott, 2008), incidents can be understood as abrupt reconfigurings of the material constitutions of practices, and the possibilities of work thereof. When harmful event befalls, it abruptly reconfigures the social/material arrangements and the possibilities to enact work practices – a calculator stops working, the network connection hangs, computer powers off, a software crashes, or a computer virus corrupts work files[3]. The abrupt material changes have direct and experienceable social implications. As Brown and Duguid (1994) explain, it is '[b]ecause the social and material aspects of artifacts and practices are interwoven, the loss of physical continuity often disturbs social practice' (p. 22). Thus, the effectiveness of business continuity measures is relational to the degree of which they enhance or are enhanced by possibilities to work; the effectiveness of plans materialize as the extent of usefulness of the plans to aid and support work in the newly transformed material conditions of work; social ingenuity materializes as the ways in which the human actor is able to enact and make use of the newly emerged material conditions; and technologies in the ways in which they enable (or do not constrain (cf. Sakurai & Kokuryo (2014)) human action. That is, the social and material aspects of work shape in important ways business continuity outcomes, i.e., what incidents occur, how they occur and with what consequences. As such, business continuity requires being sensitive and attentive to the work practices and their differential constitutions.

But how understanding of practices and their social/material constitution contributes to improving business continuity? As suggested by the above discussion, since continuity is not intrinsic to plans, social ingenuity or technologies but how they all become enacted and unite in work, the unit of improvements and analysis should be work practices. Organizations must therefore recognize that improving business continuity 'will introduce changes to working practices' (Gibb and Buchanan 2006, p. 131). As with any restructurings of organizations, when new structures are imposed, be it plans or technologies, 'they invariably alter patterns of work. Conversely, when the nature of work in an organization changes…organizational structures either adapt or risk becoming misaligned with the activities they

[3] Although something like software or files is sometimes considered as 'immaterial' rather than 'material', 'materiality is not the same as tangibility…To exist in the world as software, some specific materialization is required' (Scott & Orlikowski, 2014, p.879)

organize' (Barley & Kunda, 2001, p. 76). Indeed, often times there is a mismatch in how organizations document their work and how they actually work (cf. Brown & Duguid, 1991). Thus reliance merely on the documented plans may distort what actually takes place in practice. Further, while technologies structure action and alter patterns of work, they are not fixed, stable, and deterministic structures but become differentially enacted in practice (Orlikowski, 2000). Therefore, one possible way forward is to shift the focus from plans to planning. What this implies is that it is the process of producing the plans, the act of planning that invokes changes in work and the material conditions work, and not merely the resulting plans. Indeed, similar suggestions are also visible in the practitioner oriented business continuity methodology, ISO 22301, from International Organizations for Standardization (2012). The standard also suggests that continuity is not an end product of the planning methodology (either as plans or any other form of end product) *per se* but should be realized throughout the process as transformations in how people work and how they think about business continuity. However, it is not sufficient to describe these processes in terms of universal and rather linear abstractions (that often characterize methodologies), as '[a]bstractions detached from practice distort or obscure intricacies of that practice' (Brown & Duguid, 1991, p. 40), but investigate how the planning takes place in practice.

Existing business continuity research suggests, at least partial misalignment exists between the documented methodologies and methodologies in practice. Empirical findings from Herbane et al. (2004) indicate that the process of improving business continuity is not likely a neat and linear, but a 'messy, probably two-directional and incremental'(p. 77). Such assessment is further supported by Niemimaa and Järveläinen (2013) who suggest existing work practices and planning techniques are likely to be reciprocally related. That is, the existing work practices are likely to shape the planning techniques as much as the planning techniques shape the work practices.

As a summary, work practices have always material and social dimensions that become abruptly reconfigured when an incident befalls. Practicing continuity approach emphasizes understanding practices as amalgams of social/material arrangements, and thus, improving continuity is relational to the ways in which the planning techniques, technologies and social conditions improve the possibilities of enacting the work practices. Consequently, the unit of improvement and analysis of business continuity should be work practices.

Discussion and Conclusions

This research sought to explicate the ways in which business continuity has been approached. The focus of the research was to conceptually extend and develop further an approach that centers on the idea of practicing continuity. Despite the fact that the focus was to extend a single approach, the attempt is not to exclude, but to complement others. Indeed, each approach entails certain theoretical commitments that generate some distinctive blind spots (Orlikowski & Scott, 2008) when approaching continuity. Therefore, multiplicity of approaches may generate multiple and complementary insights of the same phenomenon, and thus widen understanding of the complexities of business continuity – each from their distinctively own perspectives. As such, the research contributes by extending the 'toolbox' of approaches for business continuity.

The approach developed here shares Butler and Gray's (2006) premise 'that individual and organizational reliability arises from both what work is done and how it is performed' (Butler & Gray, 2006, p. 212), but differs in respect to what constitutes 'work'. While their view on 'work' centers around on the cognitive aspects of work, the view taken here underlines the material aspects of work. The practicing continuity approach centers around the idea that business continuity is not embedded in plans, technologies, or human actors *per se*, but is an ongoing an active doing – a form of contextual and situated activity conditioned and enabled by the social/material configurations and conditions of work. The approach underlines that while plans, technologies and human ingenuity are each significant for business continuity, their effectiveness is not intrinsic, but arises from the ways in which they become enacted and combine when performing work. The practicing continuity thus provides a link that bridges the macro- and micro-level approaches. Failure to link the abstract, macro-level explanations and the micro-level practices at least risks overlooking or omitting the proximal explanation for variation in organizations' ability to cope with incidents, but also gives overly homogenous, cleansed, and therefore false image of organizational business continuity measures.

In order to extend and develop further the discussions around business continuity, Table 1 summarizes the existing approaches and how the practicing continuity approach contributes to understanding and improving continuity in comparison to other approaches.

Approach: Description	*Main focus*	*Blind spots*	*How practicing continuity contributes*	*Illustrative research questions*
Continuity Plans: Business continuity is largely relational to business continuity plans.	Focuses on plans and improvements of procedures to create optimal plans.	Focusing on plans (and the methodologies of their production) tells more about how plans are born out, not how organizational practices are born out of plans/planning, i.e., how the plans implicate and are implicated in organizational work.	By drawing attention to the work practices, the approach enables research to focus on the ways in which the methodologies become enacted and shaped in practice and how the methodologies can most effectively bring about changes to ways in which people work. Improving understanding on the ways in which continuity planning and work are relational may lead to improvements when designing new methodological abstractions. Further, by focusing on the work practices, new insights to how exactly continuity plans become enacted during incidents may open.	What methodological steps produce the most effective and comprehensive plans?
Continuity Technologies: Business continuity is first and foremost technological issue and determined by technology.	Focuses on advancing technologies	Focusing on technologies *per se* neglects the context of technology in use foreshadowing the multiplicities of a single technology in practice, i.e., the various ways in which users may differentially appropriate and use technologies in practice.	Draws attention to the ways in which various continuity technologies become appropriated and used when implicated in work practices under normal and incident circumstances; focuses on how technologies are used rather than what technologies are used.	Which technologies facilitate and support business continuity most effectively?
Social Ingenuity: Business continuity is relational to organizational individual and group level	Focuses on explaining and facilitating continuity-favorable social conditions.	Focusing on the social aspects foreshadows the material aspects of work, i.e., how material conditions of work restrict and enable social	By recognizing that work happens in the constitutive interaction of social *and* material conditions of the context, the approach enables insights on the ways in which the social performance is conditioned and enabled by material artifacts (such as	Which social factors influence business continuity? How to facilitate most effective social conditions for business continuity?

social conditions.		ingenuity.	technologies and plans) and how the incidents reconfigure these social/material conditions.	
Practicing Continuity: Business continuity is relational to work practices; an ongoing and active achievement.	Focuses on the situated and contextual entanglements of social actors, technologies and plans in practice.	Focusing on the interactions may overshadow the differential implications and role of plans, technologies or human actors in business continuity.	-	How business continuity unfolds in practice (as practiced)? How plans, technologies, and social conditions are implicated in work to support business continuity?

Table 1. Extending business continuity approaches

Due to the conceptual nature of this research, the lack of empirical data is a limitation that may limit the practical relevance of this research. However, 'the IS research community still relies heavily on non-empirical studies' (Chen & Hirscheim, 2004, p. 14). Nevertheless, future research should develop the practicing continuity approach further by delving into the empirical details of organizational work to understand how continuity is performed in practice. By immersing oneself into organizational work it becomes possible to foreground the practices and their constituent parts through which business continuity is performed in order to develop more nuanced, detailed, and perhaps even more truthful descriptions and theories of how continuity is practiced. Especially fruitful sites of investigation are likely to be those that have mature practices for coping with incidents and for whom continuity is imperative. Such are likely to be banks and other financial organizations, as well as organizations that are a part of societal critical infrastructures.

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3.

Sociomateriality and Information Systems Research: Quantum Radicals and Cartesian Conservatives

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Abstract

This paper provides an elaboration and comparison of two main streams of 'sociomateriality' research within Information Systems (IS) discipline. Through the rapid and controversial emergence of discussions around sociomateriality, IS research has become entangled with the radical ideas derived from quantum mechanics. The philosophical elaboration of the implications of quantum mechanics, as formulated by physicist/philosopher Karen Barad, has provided a source of inspiration and a basis on theorizing for many IS scholars. Agential realism (AR) questions the Cartesian assumption of inherent and fixed demarcation between matter and meaning, and reworks many taken-for-granted assumptions underpinning much of IS research. In contrast, some IS scholars have sought to preserve the more conservative and established assumptions, and (re)turned to critical realism (CR) in order to fit sociomateriality to IS theorizing without radically reworking the Cartesian assumption. Thence, while both make references to 'sociomateriality', their conceptions build on largely different foundations, and use very different vocabulary to describe the phenomenon of interest that easily leads to confusion and to philosophically incongruent theorizing. By elaborating and juxtaposing the two perspectives of sociomateriality and related concepts (ontology/epistemology, matter, agency, time and space), this paper extends and contributes to the prior discussions (1) by providing generic research frameworks; (2) by outlining and explaining the related lexicons; (3) and by foregrounding challenges and opportunities to conduct sociomateriality research.

Keywords: Sociomateriality, agential realism, Barad, critical realism, agency, affordances, new materialism

ACM Categories: H.0, J.4

Introduction

> When two systems, of which we know the states by their respective representatives, enter into temporary physical interaction due to known forces between them, and when after a time of mutual influence the systems separate again, then they can no longer be described in the same way as before, viz. by endowing each of them with a representative of its own. I would not call that one but rather the characteristic trait of quantum mechanics, the one that enforces its entire *departure from classical lines of thought*. By the interaction the two representatives [quantum states] (or ψ-functions) have become *entangled*. (emphasis added) (Schrödinger, 1935, p. 555)

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The radical ideas of Schrödinger that challenged the classical lines of thought in physics have transitively – through numerous modifications and adjustments – made their way to Information Systems (IS) research to challenge the conservative assumptions of the field. More precisely, it is through the philosophical work of Karen Barad (2003; 2007) – known as agential realism (AR) – that IS got itself entangled with the ideas derived from quantum mechanics. Inspired by Barad's philosophical basis of entanglement, Orlikowski and Scott (2008) introduced their view of *entanglement* that no longer was about the entangled quantum states, but about entanglement of matter and meaning. This 'radical' stance (Robey et al., 2013) provided the foundation and inspiration to formulate a theoretical argument 'there is no social that is not also material, and no material that is not also social' (Orlikowski, 2007, p. 1437). In other words, what the philosophical elaboration of quantum mechanics implied was substituting clearly demarcated social *and* material with amorphous and partly ambiguous *sociomateriality*. Sociomateriality thus contributed to solving the long standing dilemma of theorizing the relation between technology and organizations (Leonardi & Barley, 2008). By bringing 'materiality' to IS theorizing, the implication of technology as an intrinsic part of social practices could be accounted for, as, after all, the 'information systems', that are at the core of IS theorizing, have material aspects. Regardless of its extremely theoretical orientation (Leonardi, 2013), the rise of sociomaterialiaty in IS and management and organization studies has been truly phenomenal – between 2007 – 2013 over 140 journal articles were published that referred to sociomateriality, and most of them referred to Orlikowski and Scott's work as the source of the concept (Jones, 2014).

Since the inception of sociomateriality into IS, alternative conceptions have emerged, transforming sociomateriality into an umbrella term. Most notably, advocates of critical realism (CR) have formulated their view on sociomateriality that is less radical and more in line with the 'classical lines of thought' in IS and have argued for its superiority (Mutch, 2013; Leonardi, 2013). Central to these arguments is that 'materiality' could also be fitted within the socio-technical tradition of IS without radically reworking the underlying assumptions or using such complex vocabulary (such as 'sociomateriality') (Robey et al., 2013). However, simultaneously, the original formulation that questioned the nature, and even existence, of the duality of matter and meaning (Cecez-Kecmanovic et al., 2010), was shifted to find ways in which this dualistic relation could be discussed in more balanced terms (Leonardi & Barley, 2008; Leonardi, 2013). By shifting the quest, the prevalent conservative assumption of a 'Cartesian dualistic thinking, whereby the indwelling mind is distinct from the materials of the world' (Dale, 2005, p. 652) could be maintained. The purpose and necessity to entangle IS research with the radical ideas and vocabulary derived from quantum insights could thus be questioned. If materiality can be fitted to more mainstream framework, the radical reworkings and the related new lexicon (that Kautz and Jensen (2013) named as 'jargon monoxide') would become obsolete and unnecessary, therefore sustaining and reinforcing the established, normalized paradigm of the IS field.

In physics, the radical reworkings brought about by quantum mechanics was a matter of utmost necessity. The 'Copernician revolution' from Newtonian physics to quantum mechanics (Monod, 2004) was necessary as the observed phenomena could no longer be fitted into the earlier theories. Prominent physicists, such as Schrödinger, Einstein, Bohr, and Heisenberg, faced difficulties accepting the radical, and even counter-intuitive findings no longer explainable in terms of the classical physics. Even the very foundations of science – objectivity and causality – were to lose their former designations (Monod, 2004). However, the reworkings did not imply total disregard and rejection of the classical lines of thought but necessitated improving understanding of the conditions and phenomena under which they would hold true. While physics and IS are certainly far apart in terms of phenomenon of interest and methods of research, the radicals' arguments find similarities to physics – studying the complex ways in which modern technologies intermingle with and permeate every aspect of our contemporary lives requires to reconsider the foundations of IS research and develop theoretical vocabulary and conceptual arsenal very different from the established (cf. Schultze and Orlikowski (2010); Scott and Orlikowski (2014); Orlikowski (2010); Orlikowski (2007)).

Although both the ‘radical’ and the ‘conservative’ perspectives make references to ‘sociomateriality’, their conceptions broadly differ. Thus scholars, especially for newcomers, who wish to apply sociomateriality will need to distinguish these different perspectives and build on conceptions and vocabulary that are in line with their particular perspectives. Improper use will lead to confusion and to conceptual mélanges that are philosophically incoherent and incongruent. This paper contributes to this challenge by juxtaposing the radical and the conservative perspectives and their related conceptions (ontology/epistemology, agency, matter, time and space). Further, the paper identifies challenges and opportunities emanating from each perspective’s philosophical foundations. It seeks to unveil some of the mysteries and difficulties in apprehending and applying sociomateriality to study IS phenomena and clarify the language used. By doing so, the paper extends earlier discussions on sociomaterial perspectives (Leonardi, 2013; Scott & Orlikowski, 2013; Mutch, 2013; Kautz & Jensen, 2012; Kautz & Jensen, 2013; Jones, 2014).

The paper proceeds by first providing an overview of the philosophical foundations in relation to sociomateriality and positions them alongside wider discussions within and outside the IS field. Second, the differences between the perspectives are elaborated by focusing on four central concepts. Third, the discussion section provides an illustrative research framework for both perspectives to be used as a basis to conduct sociomateriality research, and outlines the lexicon used to describe sociomaterial phenomenon. Last, conclusions are drawn and the discussions are connected to paradigmatic nature of scientific progress.

Philosophical Foundations of Sociomateriality in Information Systems Research

The emergence of discussions around 'sociomateriality' within IS seems to reflect and draw inspiration from multidisciplinary interests towards 'materiality'. While IS scholars have been struggling with the relation between social and technology (Orlikowski & Baroudi, 1991; Leonardi & Barley, 2010) the concern seems to reflect broader 'longstanding dilemma as one between sociality and materiality' (Woolgar, 2002, p. 265). Indeed, the dilemma is very longstanding, as the philosopher and historian of philosophy and science, Bertrand Russell (1945), already recognized: 'The [given/fixed] distinction between mind and matter, which has become commonplace in philosophy and science and popular thought, has religious origin, and began as the distinction of soul and body' (p. 134). However, it has been only recently that social sciences in general have shown increasing interest towards 'materiality' – the part that materiality plays in sustaining and stabilizing social life. The increased interest has been coined elsewhere as the 'material turn' or 'new materialism' (Pels et al., 2002; Dolphijn & van der Tuin, 2012), contrasting it with 'older' (or traditional) materialism (Barad, 2007). Especially, 'those pre-modern philosophers such as Duns Scotus, Lucretius and the whole Stoic tradition, whose work is not (that) effected by dualist thought, are being read like never before' (Van der Tuin & Dolphijn, 2010, p. 167).

Karen Barad's philosophical approach, agential realism (AR), is seen as a possible and promising way to overcome, or at least interrogate, the dilemma. She is considered as one of the most influential and important new materialists (Dolphijn & van der Tuin, 2012; Lemke, 2014) and her work has been influential across a broad spectrum of disciplines, such as Science and Technology Studies (STS) (e.g., Hitchin, 2009; Pinch, 2011), feminist theory (see Kvinder, Køn & Forskning, vol 1-2 (12)), cultural studies (see Rhizomes forthcoming[1]), political science (e.g., Coole (2013)), and physics (e.g., Josephson, (2015a; 2015b))[2]. After finding her way to IS research through Orlikowski and Scott's (2008) conception of entanglement, her work has drawn wide attention of the IS and management and organization studies, as evidenced by, but not limited to, the dedicated *MIS Quarterly* special issue on sociomateriality (Cecez-Kecmanovic et al., 2010)) and keynotes and articles in management and organization studies related venues and collections (e.g., Carlile et al. (2013)). AR is a philosophical approach, a world view that is a set of beliefs that 'delineate a way of seeing and researching the world' (Chua, 1986, p. 604). It shares similarities with Actor Network Theory (ANT) (see Latour (2005) for an overview of ANT)(Leonardi, 2013; Gond et al, 2015), 'but her more radical stance on materiality – derived from quantum physics – considers the intimate entanglement of non-human and human elements that are both made of matter' (Gond et al., 2015, p. 9). Like any other philosophical worldview, AR is not a theory of the relation between organizations and technology per se but an underpinning, a bedrock onto which build such theories. Thus, understanding the underpinnings is of significance as they influence what aspects of the world are considered important and why. I will leave agential realism for now and return to it in the next section, in order to turn to other foundations of sociomateriality that reflect a whole different set of beliefs – those embedded in the philosophical approach of critical realism.

Discussions around CR within IS started much earlier than discussions around sociomateriality. Perhaps most thoroughly and visibly CR has been discussed by John Mingers (see Mingers (2004a,b,c); Mingers and Willcocks (2004), for example), who also suggested it as a common philosophical worldview for IS research (Mingers, 2004b)[3]. Critical realism has also received significant attention in the IS community, as evidenced by, but not limited to, the *MIS Quarterly* special issue on critical realism (see *MIS Quarterly* 37(3) 2013). While past studies analyzing IS research has asserted that the research follows one of the three philosophical world views of positivism,

[1] http://rhizomes.net/files/future.html#barad
[2] I would like to thank Gijs van den Heuvel for bringing this to my attention.
[3] See also Klein (2004), Monod (2004), and Mingers (2004a) for a debate that followed the suggestion.

interpretive or critical (majority of research following positivism) (Chen & Hirschheim, 2004); Orlikowski & Baroudi, 1991; Richardson & Robinson, 2007), Smith (2006) argues most IS research is compatible with CR. That is, he argues that past research can be largely fitted within the framework of CR which is in line with Minger's (2004a) view that CR is a broad framework that can subsume positivism, interpretive, and critical world views. Thus, CR should not be seen as *the* classical line of thought but as an extension mostly in line with it. Such a view is typically considered as conservative (Linstead, 2004), not in the political sense, but as valuing the established and traditional practices of the discipline. Not surprisingly then, CR evoked the sense of *déjà vu* in Klein (2004), who posed the rhetorical question 'what's new in critical realism?'.

The discussion on CR in relation to 'sociomateriality' can be linked to Paul Leonardi's work in IS and management and organization studies (e.g., Leonardi, 2011; Leonardi, 2012; Leonardi, 2013). His work has inspired a number of other research published in (top) IS outlets, such as Introna and Hayes (2011) and Bratteteig and Verne (2012). Leonardi's view of sociomateriality is *compatible* with critical realism rather than directly founded on it (Leonardi, 2013). Indeed, CR in the works of its founder, philosopher Roy Bhaskar, is neither about sociomateriality *per se,* nor about the role of materiality of social affairs. As Schatzki (2010) argued, in CR 'physicality and nature are mostly irrelevant to the character and progress of social phenomena, instead forming background conditions against which social affairs proceed' (p. 126). That is, the ideas (and assumptions) inspired by CR have been extended *to explain* sociomateriality as the process of interlocking of humans and technologies.

While the philosophers never encounter each other's' work in their respective oeuvre, Bhaskar nevertheless directly contests Barad's starting point, and thus, the foundations of AR. Where Barad, as a graduate in particle physics, takes quantum mechanics as the starting point for her philosophical arguments, Bhaskar takes the view that it is 'always a mistake, in philosophy, to argue from the current state of a science (and especially physics)' (Bhaskar, 2008, p. 179). Barad's reverence on physics has also been a source of direct criticism (as especially pointed by Mutch (2013) and Pinch (2011)), and has evoked even as harsh criticism as turning social sciences a subservient to physics (Jarzabkowski & Pinch, 2013). Indeed, In contrast, Monod (2004) centered his criticism towards CR on its inability to account for quantum mechanics, which according to him, render it invalid in the light of physics discoveries. What is of interest here is to outline the differences on the conceptualizations of sociomateriality emanating from these foundations.

As the differences emanate from and reflect their particular philosophical positions, it seems as a feasible way to proceed with the comparison. However, as Bhaskar and Barad address different audiences and contribute primarily to different traditions, the comparison of the philosophies is not straightforward. The focus here is on certain key concepts relational to sociomateriality that are broadly useful and of which they both have a view of.

Juxtaposing Sociomaterial Conservatives and Radicals

As suggested in the previous section, the philosophical foundations are a fruitful point for juxtaposing the sociomaterial radicals' and conservatives' perspectives. The focus here is to elaborate those aspects that are different, and by doing so, provide a discussion and a comparison of both perspectives as a basis for further discussion in the next Chapter. The comparison focuses on four aspects: (1) Ontology (epistemology); (2) Matter; (3) Agency; and (4) Time and Space. The rationale is that ontology and agency have been at the core of the new materialist philosophies (Coole & Frost, 2010), sociomateriality *is* about matter, and time and space are central to IS research (Leonardi, 2013; Mutch, 2013). The discussion proceeds by first elaborating ontological (and epistemological) aspects, moves then to matter, and then agency. Last, time and space are discussed. Appendix A provides a brief overview of the differences. While exposing the underlying assumptions, the discussion will gradually unfold a more detailed view of what sociomateriality means for each view.

Ontology and Epistemology

While the conservatives maintain the traditional philosophical dichotomy that separates questions of ontology (i.e., what the world is like) and epistemology (i.e., how knowledge of that world can be gained), the radicals view the dichotomy as a heritage of (purportedly) false assumptions embedded in Cartesian thinking that separates *res cogita* (mind) from *res extensa* (matter) (Orlikowski, 2010). From this radical perspective, there is no clear distinction between ontology *and* epistemology but only 'the study of practices of knowing in being' (Barad, 2007, p. 185) that is *onto-epistem-ology*. What this difference also implies is that while CR is concerned with *transcendence*, similar to other new materialist philosophies, AR is about *immanence* (Coole, 2013). Consequently, the following discussion also differs.

Conservatives

Conservatives build on a stratified ontology in which the world is assumed to exist in three hierarchical strata: (1) empirical; (2) actual; and (3) real (Collier, 1994; Mingers, 2004b; Klein, 2004). The empirical contains perceivable and experienceable events that are emergent manifestations of underlying mechanisms at the lower strata. The mechanisms have to be inferred from empirical events as there is no direct unmediated access to the world. This mediation 'distorts' and enriches the objective aspects of the world with subjectivity. Consequently, the entities and mechanisms at lower strata cannot be directly observed but has to be inferred through human ingenuity. Through the ingenuity, theories about the entities, and causal mechanisms can be devised as explanations of the perceived or experienced events. A transcendental question (i.e., what must be the case for X to be possible (Benton & Craib, 2001)) assists to transcend to lower strata to formulate theories that are always partial and fallible. That is, the actual is a subset of the real that includes events (and non-events) generated by the lower stratum entities and structures when their mechanisms or tendencies are enacted or activated (Wynn & Williams, 2012), whereas the stratum of the real is the 'lowest' stratum and represents the independent world of 'things' that have causal mechanisms (Wynn & Williams, 2012; Volkoff & Strong, 2013). Since the world can never been known directly, what the actual entities are cannot be known for sure. As Bhaskar (2008) argues: 'if the stratification of the world has an end, i.e. if there are 'entities' which are truly ultimate—and I can see no reason for supposing this must be so—and the scientist has achieved knowledge at that level, he can never know that the level is ultimate' (p. 162). Central to the stratified ontology is that while the lower strata mechanisms can be used to explain the perceived or experienced event, the event cannot be reduced to those mechanisms (Benton & Craib, 2001). That is, a higher stratum has always emergent properties. For instance, having a headache from watching the computer screen for too long may be explained by physiological changes but cannot be reduced to those changes. In addition, it would not be possible to study the physiological changes of a headache unless that headache was first experienced (not necessarily by the person studying it). After reviewing this generic ontological (and epistemological) framework of CR, it is now possible to position sociomateriality to this framework.

Conservatives build on the assumption that sociomateriality emerges through a process of interaction/interlocking of (discrete) entities that are social (/human) and material (/technology); they *imbricate* (Leonardi, 2011). Imbrication is an emblematic mechanism of interaction/interlocking in which two discrete and different types of components commingle to form something emergent; a waterproof tile roof in its original Roman and Greek use of the concept, and sociomaterial in the latter use. Sociomateriality then is an emergence of the lower strata, and therefore not reducible to its component parts. For instance, what employees can achieve with smart phones and how they achieve it is not reducible to employees or to smart phones, but can be explained in terms of mechanisms of their interaction. These mechanisms will be elaborated later.

Radicals

The radicals' view builds on a network ontology that presupposes the world as relational and the '[material and social] agencies are only distinct in relation to their mutual *entanglement'* (emphasis added)(Barad, 2007, p. 33). According to this relational ontology, there are no individual 'things' or discrete entities, only networks composed of things (known as *agencies*) that exists in relation to their mutual constitution. In this mutual constitution, known as *phenomenon*, things receive their boundaries and properties in relation to one another. To signal the inseparability, radicals have brought forth a neologism, *intra*-action (in contrast to interaction) (Barad, 2007; Schultze, 2011; Nyberg, 2009), to indicate the within-phenomenon nature of the existence of agencies and their relata. While this may sound highly philosophical, it relates well to how we encounter objects and their capacities in everyday life. The practice of hammering a nail to a wood, is neither solely dependent on the hammer nor on the person driving the nail, but on (the intra-actions of) the hammer, the hammerer, the nails, the wood and so forth. Thus, this does not mean that there is no social *and* material. Rather, the claim is that they do not exist as clearly demarcated entities that await to be organized into categories and concepts prior to our engagement with that world. That is, what is social and what is material become enacted in practice. However, this is not a constructivist position (i.e., that world only exists as we construct it), but radicals view that as soon as we engage with the world we are inescapably *a part of* its intra-acting dynamics (Barad, 2010). As Mazmanian et al. (2014) put it, '*social* and *material* are each simply selective projections of a tangled whole' (original emphasis)(p. 832). This entangled whole, the differential projections of the ontological network that is phenomenon, is 'sociomaterial'.

As selective projections, what becomes 'material' and/or 'social', is not fixed or given, but result from *material-discursive* (Barad, 2007) practices. As Rouse (2004) explains, concepts and materiality are relational to each other in such a way that world acquires its boundaries and concepts acquire their definite content together. That is, there are no ‘things’ that would pre-exist in the world prior to our engagement with that world. This is what Barad (2007) means when she, building on Nietzsche, warns us to not take our language too seriously. Concepts are not mirrors of the world that reflect certain a priori demarcated parts of the world, but concepts attest their meaning in doing and always imply certain exclusions and inclusions. The ontological indeterminacy is resolved as through material-discursive practices certain demarcations (known as *agential cuts)* become enacted (Barad, 2003). When we design information systems for ‘users’ but exclude, for instance, disabled users from our concept of users, we make agential cuts through which the concept and the world becomes differently enacted intelligible but also exclusions and inclusions that matter. That is the concepts and ontology are a practical orientation and a doing; matters of a specific *apparatus* in Barad’s (2007) terms. Thus, what we know and how we know it are not separate and distinct concerns but entangled. As such, the world is in constant becoming as 'phenomena are forever being reenfolded and reformed' (Barad, 2007, p. 177). This onto-epistemic foundation has profound implications also to other conceptions.

Matter

Conservatives

Conservatives assume a world of matter that is 'out there' awaiting for discovery; matter exists *in* the world. Matter is the substance of which different things are made of. Material things (each with their own properties/capabilities) exist in the world as clearly bounded individual entities that await for discovery through scientific and other means. These things that exists ‘out there’, once uncovered, become represented as concepts. In this sense, matter is passive and awaits humans to inscribe them with meaning and label. The difficulty then is to discover those entities, to transcend beyond our (deceptive) senses, and conceptualize the discovery. Information systems are also material entities that exists in the world as well defined entities with labels such as Enterprise Resource Planning (ERP) system or Customer Relations Management (CRM) system. Despite their ambiguity, these labels are assumed to be universally accessible representations of certain materials, and thereof, technologies. As such, scholars interested in (information) technologies have little reason to make references to ‘matter’ as it is merely a broader category of and a substance of technology. Indeed, for conservatives matter only serves 'to remind those who would not normally make an explicit consideration of technology in their work to attend to the importance of the technical bases of organizational life, without using the term “technology” directly' (citation marks his) (Leonardi, 2013, p. 65).

Radicals

From the radical perspective, matter is a historical process. Due to the rejection of a fixed and inherent dichotomy of social and material, there is no ‘external’ outside from the ‘internal’ (e.g., from the self and the mind) for the matter to occupy. That is, matter is not situated *in* the world ‘out there’, but, as Barad (2007) philosophically states it, 'matter is worlding in its materiality' (p. 181). What becomes enacted as ‘matter’ is relational to material-discursive practices and the specific apparatus through which the world is made intelligible. Thus, ‘technologies’ neither have inherent properties, boundaries nor meanings, but result from specific material-discursive practices (Orlikowski, 2010).

For radicals, matter carries traces of the process of its becoming as its history. As agencies *congeal*, they sediment as traces of matter’s historical becoming. As Barad (20007) explains, '[a]s the rings of trees mark the sedimented history of their intra-actions within and as part of the world, so matter carries within itself the sedimented historalities of the practices through which it is produced as part of its ongoing becoming – it is ingrained and enriched in its becoming' (Barad, 2007, p. 180). That matter is ingrained and enriched in its becoming implies the process of matter’s becoming is relational to its past (i.e., there is a path dependency). This means that 'matter plays an agentive role in its iterative materialization' (Barad, 2007, p. 177). Thus, the process of becoming is not that of unfolding but of *enfolding* (Barad, 2007). While all this may sound disconnected from the world and reality as IS scholars encounter it, the information systems we encounter in organizational realities often sediment decades of development practices. The year 2000 ‘Y2K’[4] problem concretely reminded of the implications of this sedimentation as organizations realized their information systems, developed over decades, sedimented programming practices in their software code that shortened four digit year into two digit form, making the systems’ behavior unpredictable on the cusp of new millennium as the year changed from 99 to 00. What resulted was massive, global-scale update operations in which the software developers had to rework the software sediment and build onto that which was given to them by the past.

[4] See https://en.wikipedia.org/wiki/Year_2000_problem

Agency

Conservatives

Agency from the conservative perspective is viewed as a capability to do things. As such, agency is broadened as being solely a property of humans to include also technologies. While from this view, they both have agency, technology lacks intentionality (Leonardi, 2011). Technology that performs tasks or takes action, such as a system running a scheduled batch job without human intervention, expresses its agency (Robey et al., 2013). When humans interact and imbricate with technologies, they form emergent *affordances* that shape their agency. Affordances reside neither in the social nor in the material alone, but in the relationship (Leonardi, 2011; Volkoff & Strong, 2013) as mechanisms at the ontological stratum of the real (Volkoff & Strong, 2013). While various conceptions of affordances exist (Robey et al., 2013) the focus here is on the conception relative to sociomateriality and critical realism.

Persons' ability to express their agency by transforming intentions into (intended) actions is shaped by technology's inherent capabilities and the person's history with same or similar technology. These episodic encounters with technologies form a space of enactment that regulates volition. Affordances are then materially and historically conditioned space of action in which human volition operates. This kind of agency is likely to be very intuitive for IS scholars. As users interact and continue to use a specific technology, a mobile phone for instance, both the technological artifact and past use shapes the way the technology is used and continues to evolve over time. Further, when the users change their mobile phones to another (similar or same) one, the past experiences continue to shape the consecutive use. In addition, the technological artifact has inherent properties that are fixed across space and time. That is, when a mobile phone is taken from one context to another, the material artifact itself and its ontology remains the same. As such, variation in technology use across contexts is explainable in terms of users' history with that or similar technology. Thus, affordances exist only through enactment that is actualized (i.e., brought to stratum of actual) through social agency.

Radicals

The radicals' ontological position of entanglement has profound theoretical implications for the conception of agency. Due to the denial of existence of discrete entities with inherent boundaries and properties, agency is not viewed as a property someone or something has (whether humans or non-humans) but relational to a (human/non-human) collective. Agency, 'rather than being thought in opposition to structures as forms of subjective intentionality and the potential for individual action – is about the possibilities for changing the configurations of spacetimematter relations' (Barad, 2007, p. 230) ('spacetime' will be discussed later). By positioning agency as the possibilities for reconfiguring, no single 'thing' is given priority to solely determine the course of events. Intra-actions condition the *possibilities* for *reconfiguring* a phenomenon (Barad, 2007) and give raise to agency as the possibilities for changing/shifting the social/material constitution of the phenomenon. These possibilities are conditioned by the past and the agential constitution of the phenomenon. However, the possibilities are not static but reconfigure through each iterative intra-action. Further, this kind of 'distributed' form of agency also reminds that the use of technologies is not merely a dyadic interaction between user and technology, but involves other agencies that can have an effect. For instance, hammering a nail to a wood is neither solely dependent on the hammerer's intention or ability (whether mental or physical) to use a hammer nor on the hammer's materiality but also on the quality of the nails, on the hardness of the wood, and so forth. Further, missing the nail when hitting, will reconfigure a whole lot of future possibilities by excluding some (e.g., if the wood was broken by the missed hit) but also opens new possibilities and future trajectories.

Time and Space

Conservatives

As imbrications are episodic interactions of humans and technologies over time, time and space are important parts of the explanation. Proximity to technology in physical space where the interaction takes place gains priority over physically distant events, and time as measured against universal 'clock time' gains priority over other measures of time. That is '[o]rganizations and people's practices exist in time. They unfold and change along a temporal plane' (Leonardi, 2013, p. 67). As such, time and space are expected to provide objective measures, a backdrop, against which to measure change and progress (such as users' CRM usage patterns over years). Such view encourages longitudinal studies, as they enable analysis of the iterative interaction/interlocking (i.e., imbrication) of humans and technologies to explain the kinds of patterns they form through their reciprocal interaction.

Radicals

Radicals rework time and space as timespace (matter). Central to their notion is that '[s]pace and time are phenomenal, that is, they are intra-actively produced in the making of phenomena; neither space nor time exist as determinate givens, as universals, outside of phenomena' (Barad, 2010, p. 261). Thinking time and space as phenomenal does not exclude the possibility to make references to universal time or geographic distances, but it does draw attention to other possible conceptions of time and space. The benefit of 'thinking in terms of networks is that we get rid of "the tyranny of distance" or proximity; elements which are close when disconnected may be infinitely remote if their connections are analyzed; conversely, elements which would appear as infinitely distant may be close when their connections are brought back into the picture' (Latour, 1996, p. 4). This is also what Barad (2007) means when she argues that foregrounding boundaries and connectivity (i.e., matters of topographies) might have more significance than geographic and clock measured distances[5]. Such conception seems especially useful for IS scholars, as information systems create spaces and reconfigure realities.

The (virtual) space created by IT is 'a simulacrum of the site, not in the sense of a substitute for it, but rather of a place in which to work, with its own specific materialities, constraints and possibilities' (Suchman, 2007, p. 3). That is, for radicals, IT reconfigures users' space in such a way that geographic distances lose their prior significance. Such (virtual) space is not an empty space but connects users and technologies (as in the case of social media for instance) as well as (physical) spaces. The intra-actions between the users and technologies (and other materialities) create realities that would cease to exist in the absence of technologies (or users). And in these realities what matters is the connectivity rather than where one physically resides. This is neither to say that technologies connect spaces by poking 'holes' through time and space nor that technologies would reconfigure that which is geographically distant as phenomenologically local, but that the intra-actions give raise to new realities. They are realities that are jointly performed by technologies, software, users, algorithms, spaces, and connections, to name a few. As such temporality is 'enacted through ongoing materializations in practice rather than traced through unit-by-unit measurements of clock time' (Scott & Orlikowski, 2014, p. 878).

[5] See also Barad (2001, p. 75) for an insightful example of how technologies reconfigure time/space.

Discussion

This study elaborates the differences in the two main perspectives of sociomateriality research. The comparison shows, that, in line with other similar studies, the perspectives are largely different (e.g., Scott and Orlikowski (2013); Kautz and Jensen (2013); Mutch (2013)). These different assumptions and theoretical commitments entail implications for conducting IS research (Orlikowski & Baroudi, 1991). First, conceptual frameworks that combine the earlier discussion into a coherent whole are provided for both perspectives. Second, a conceptual vocabulary to discuss and describe sociomaterial research is provided with use examples. Third, opportunities and challenges to conduct sociomateriality research are provided for both perspectives. These three discussions extend the earlier research by lowering the barrier to conduct sociomateriality research and promote theorizing and empirical analysis that are consistent with their respective philosophical underpinnings and conceptual vocabulary. Last, the paper is connected to earlier debates on sociomateriality and extends the debates by providing an alternative interpretation of some of the past criticism in the light of the elaboration provided here.

Conceptual frameworks for sociomateriality

Building on the elaboration of both perspectives in previous section, Figure 1 illustrates abstract conceptual frameworks for both sociomateriality perspectives. The conceptual frameworks provide a basis for IS researchers conducting sociomateriality research.

The assumption of the primary ontological unit greatly shapes the proceeding analysis (cf. Leonardi (2013)). For conservatives, who take the discrete entities (and the dualistic social/material) as their starting point, the research proceeds by theorizing ways in which the two may be brought together. The quest then is to understand the mechanisms through which the social interacts with material, i.e., the process of imbrication as regulated by the affordances as the space of enactment. While there are other applications for the conservatives' view, it seems to be especially useful lens for studies at the human/technology interface that study the development/evolution of IS adaption and use over time. For instance, use of mobile devices, such as smart phones, might be studied as a process varying over time as the user iteratively 'interlocks'/interacts with the technology and the affordances evolve over time. Such accounts of use would not only focus on IS use as solely mental but necessitates accounting for the role that materiality of technology plays in shaping the use.

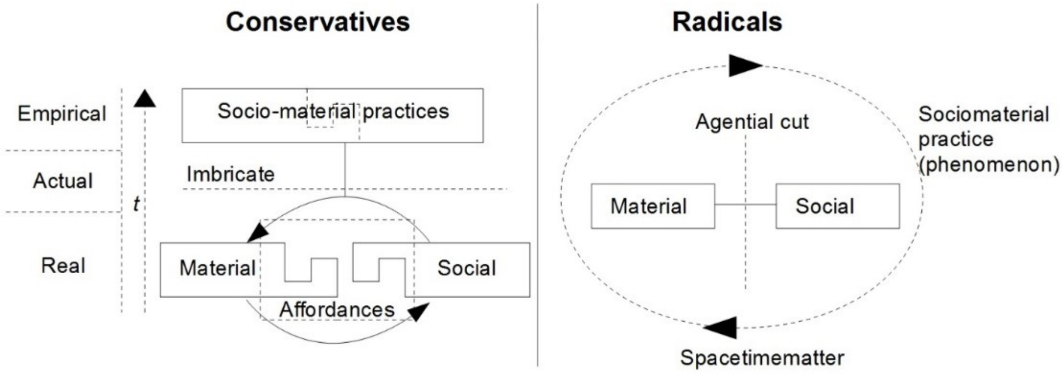

Figure 1. Frameworks for sociomateriality research

That is, it helps to 'unpack' and understand the constitution of IS use, as sociomaterial practice, and go beyond explanations of user perceived usefulness of IS into explanations of evolving affordances. Understanding the (material) constitution of practices is likely to be meaningful for explanations of why certain technologies become used while others do not, and why certain technologies are used in the way they are used.

In contrast, radicals take the entanglement as starting point (indicated as the 'sociomaterial phenomenon' in Figure 1.), leading to interrogate the duality that is taken-for-granted in the conservative's view. The right side of Figure 1 illustrates the (temporary) enactment of social/material emerging as agential cuts creates and mark the separation, simultaneously giving rise to the relata of intra-activity between social and material. The radicals' theorizing thus underlines the ways in which the dualities become enacted in practice and with what consequences (cf. Nyberg (2009); Schultze (2011)). Further, the solid lines around the social and material on right side of Figure 1 convey the idea of determinately bounded and propertied entities, as they are constitutive of the phenomenon. Further, the phenomenon is not any fixed representation of any one aspect or part of the world; neither are any boundaries or properties determinate from here-to-there, but configured and reconfigured in each iterative intra-action (as are the possibilities for future intra-actions too). Thus, what has materialized becomes enfolded in the future iterations of intra-actions creating a strong sense of path dependency (i.e., past limits the options of the future). As Kimberly and Bouchikhi (1995) recognize, '[organizational] [t]ransformation cannot simply be mandated. To be effective, it must be undertaken in a way which builds on rather than runs over the past' (p. 9). The path dependency is not merely a negative and constraining effect but is as much a positive effect; as possibilities are excluded, new possibilities always surface. By focusing on the phenomenon, AR encourages analysis that are not merely about the different uses or differences in the use of technologies but on the broader implications and realities the technologies co-create.

Sociomaterial lexicon

When describing phenomena, language and the concepts used to describe and orient oneself towards the empirical play an important and performative role. As Rouse (1998) puts it, '[t]hey [lexicons] are thus not merely verbal, but are rather an inextricable configuration of words and things; mastering the lexicon means acquiring the skill to recognize its appropriate application in various settings, and to encounter the world in those terms. The intelligibility of the world through the use of a lexicon is less a presupposition than a practical commitment' (p. 46). Sociomaterial theorizing has brought along with it a significant number of neologisms, and redefined old concepts to fit new context (see for instance Ciborra (2006) for a very different use of the concept of 'imbrication'). Simultaneously, as Corley and Gioia (2011) wit, 'our distal language often seems to elide the relevance of our second-order theoretical constructs from the proximal parties whose experience we are trying to explicate.' (p. 21) However, these 'second order theoretical constructs' we use to communicate the empirical details and context-specific language to our peers signals both theoretical orientation and practical commitment but also connects us to the past and to our peers.

Table 1 builds on the earlier discussion and outlines a sociomateriality lexicon and suggests potential uses for each concept. That is, it aims to translate the 'jargon monoxide' (Kautz & Jensen, 2013) into more manageable and understandable form. Table is organized in such a way that *comparable* concepts from each perspective are given on each row.

Table 1. Sociomateriality research lexicon

Radicals (AR)	*Conservatives (CR)*
entanglement Describe the foundational onto-epistemic commitment of inseparability of matter and meaning as the starting point for analysis.	*stratification* Describe the ontological commitment to a stratified reality (real, actual, and empirical).
intra-action Explain how relations always pre-exists 'things', that is, show how 'things' exists only in relation to other 'things' and how the properties and boundaries of a 'thing' are dependent on the relation.	*interaction* Describe how things come together and produce emergent features through their interaction.
(re)configuring Describe changes in the constitution of a phenomenon, e.g., how the phenomenon and the agentic possibilities change through shifting/changing intra-actions.	*imbrication* Show how user perceptions (of technology) change through recurrent and episodic interactions with technology and how interactions explain variation in the emergent whole (e.g., change patterns in the use of technology).
agential cut Describe how boundaries of matter and meaning become differently enacted in practice and with what consequences, e.g., show how 'social' has material aspects and how they matter.	No equivalent
possibilities Describe the space of reconfiguring that forms also onto-epistemic boundaries of agency, e.g., show how materiality shapes agentic capacities.	*affordances* Describe the (user) perceptions of what a certain material object (e.g., technology) permits to achieve (i.e., 'affords') and how those perceptions are relational to the object's materiality.
phenomenon Describe the network of agencies that are only meaningful and reconfigure as part of the described phenomenon. Notice that phenomenon is not 'emergent' (i.e., something that is more than the sum of its parts) as there are no 'parts' without the whole.	*emergence* Describe how the observed behavior is more than the sum of its underlying parts but also describe how the parts may explain the emergent behavior.
enfold Describe how the unfolding events are always relational to what took place before and how the unfolding event is enriched by and enriches the past.	*unfold* Describe how things happened over time and/or place, e.g., how technology use varied during the study period and different contexts.
congealing / sedimentation Describe the (historical) development of matter (becoming) through practices and how these practices have led to certain materialization(s).	No equivalent
material-discursive practices Describe how practices have material and discursive aspects and how practices materialize phenomenon in certain ways.	*material and/or discursive practices* Describe how certain practices are discursive (e.g., speech acts) and how others are material (e.g., using a tool).
apparatus Describe how knowledge of the world is always produced as part of that world and is relational to the material-discursive practices through which we engage with and know the world.	*mediation* Describe how our knowledge of the world is always partial and fallible as what we know we know in the mode of the knower, e.g., the world is never directly accessible but distorted by our senses.

Opportunities and Challenges for Conducting Sociomateriality Research

Any philosophical or theoretical stance entails certain a prior commitments and assumptions that render certain parts of the world and reality more salient than others (Chua, 1986). As such, some research questions and insights are likely to follow more easily from one perspective than another. Table 2 outlines both challenges and opportunities emanating from each perspective.

Conclusion

This paper focused on the differences of two main streams of sociomateriality theorizing within IS referred to here as radicals and conservatives. The conceptions, the philosophical assumptions, and the language they use seem so dispersed and far apart that concluding that they speak from different paradigms – but to a common audience – seems warranted. The radical formulation of sociomateriality is not merely a matter of theoretical orientation and appropriation of (new) theoretical concepts, but it is a philosophical reorientation towards the world. Broadly, it is a reorientation from a human-centric paradigm to a polycentric paradigm. That is, where traditionally the social sciences have placed the human at the center of theorizing, radicals' position asserts 'humans' are a *part of* the world's becoming.

Kuhn (1996) famously outlined an idea of sciences progressing through paradigms (i.e., implicit rules that govern scientific practices of knowledge making) in which the prevailing paradigm shifts or becomes replaced through scientific progress.

Table 2. Challenges and opportunities for sociomateriality research

Radicals (AR)		***Conservatives (CR)***	
Challenges	***Opportunities***	***Challenges***	***Opportunities***
Ontology (epistemology)			
Underlining becoming and change over stability may lead to explanations that downplay, for instance, stable and routinized IS use. Focusing on relations may overshadow explanations related to attributes of technology that are stable across relations (e.g., different contexts) (cf. Leonardi, 2013).	Emphasizing the relational nature of ontological boundaries and properties provides foundations for understanding changes and variation in technology use across user-bases, technologies, contexts and time. Leaning on network ontology does not predefine hierarchical scales (or layers) which affords explanations where micro-scale events may have macro-scale consequences and vice versa (as traditionally conceived) (see for instance Barad (2010)).	Emphasizing the role of underlying mechanisms in explanations (e.g., imbrication) may overshadow that which is immediately present and visible in lieu of that which is transcendental. Taking social as ontologically separate and distinct from material encourages social *or* material explanations rather than their mutual reciprocity, e.g., the materiality of cognition (cf. Clark & Chalmers (1998))	Focusing on stratification provide explanations of the deeper structures of observed and experienced phenomenon, and provides a general and integrative framework for social, psychological and material explanations, e.g., different explanations explain different mechanisms and different strata.
Agency			
Focusing on the ontology of agency and agentic capacities may overshadow explanations related to (human) motivation, and reasoning for realizing those capacities such as the role of volition and affection (cf. Stein et al., 2014).	Decentering agency and viewing it as relational to the constitution of a phenomenon enables explanations that do not privilege humans as having priority to determine outcomes.	Focusing on agentic capacities emerging from the interaction of humans and technologies (affordances) downplays the role and influence of the broader (material) context for the interaction, e.g., interaction that is dynamically shaped by intelligent algorithms and/or other (non-local) users (cf. Orlikowski & Scott, 2015).	Studying boundaries/space of agency as affordances foregrounds explanations on why some users use same technologies differently, and how this use is historically and cognitively formed that may also explain how these users will use similar technology.
Matter			
Underlining the reconfiguring and changing nature of matter, its volatile boundaries and relational properties, may downplay explanations related to designed and built-in features of technologies and over-emphasize the role of the historical development of matter ('sedimentation').	Considering matter as dynamic and changing and thoroughly implicated in 'social' affairs draws attention to the role of materiality in performing those affairs, e.g., the entanglement of 'social' identity and technology (cf. Schultze, 2014).	Considering matter as a backdrop for social affairs may downplay its active role in producing those social affairs and fade matter into background (cf. Schatzki (2010)).	Assuming that technology has stable and inherent properties relational to its materiality enables comparative studies between contexts using the same technology to identify and explain the role of the social mechanisms.
Time and Space			
Focusing on time and space as enacted in practice may downplay the duration of change (as measured by universal "clock time") as (part of) explanation, such as evolutionary development.	Focusing on how things are connected and related to each other rather than on the physical distance are likely to provide meaningful explanations in contemporary technology-connected world, e.g., proximity in virtual space rather than in physical space (cf. Wilson et al., 2008).	Focusing on the "clock time" may emphasize longitudinal changes on the cost of changes and events that take place within short period of time, e.g., moments of improvisation give raise to and necessitate different types and scales of time that defy measurement against clock time (Ciborra, 1999).	Measuring duration of change as it unfolds over time enables comparisons across studies, e.g., why imbrication took longer in site A than site B.

However, as Mingers (2004a) points out, this 'idea of paradigms replacing each other over time has developed, particularly within social science, to the idea of there being competing paradigms existent at the same time' (p. 90). The paradigmatic fragmentation is hardly new for any IS scholar. After all, the categorization and framing of IS research to positivist, interpretive, and critical paradigms is long-standing and widely accepted. There will never be *a* paradigm but several paradigms that simultaneously coexist and coevolve. From this view, the radical perspective is another addition to this 'fragmented adhocracy' as Landry & Banville (1992) characterize IS discipline.

As Rouse (2013) explains, Kuhn's 'point was not that scientists accept paradigms dogmatically, without justification, but that *paradigms are not* appropriately *seen* even *as candidates for justification'* (emphasis added) (p. 61). As such, the challenge for the radical perspective is to establish itself among and in relation to the other paradigms. This paper has contributed to establishing the paradigm by lowering the barrier to conduct research according to the paradigm. To this extent, '[p]aradigm change is then a conceptual and practical reconfiguration of a scientific domain, as a ''work-world'' in which the primary scientific task is the further development of a conceptual grip.' (Rouse, 2013, p. 62).

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Appendix A. Brief overview of sociomaterial conservatives and radicals

	Sociomaterial Conservatives	***Sociomaterial Radicals***
Sociomateriality	Sociomateriality is the interlocking of social and material through process of *imbrication* in such a way that they become seemingly one. They, however, maintain their ontological separability as discrete entities.	The world is always and already sociomaterial in its differential becoming. Any separation is temporary and relational to their mutual constitution (that is *phenomenon*).
Ontology / epistemology	• Stratified ontology. • Primary ontological unit is a discrete 'entity' (Bhaskar, 2008). • Higher strata has emergent powers dependent on but not reducible to lower strata powers (Bhaskar, 2008); (Wynn & Williams, 2012). • A world of 'things' exists out there acting under certain circumstances by the virtue of their essential nature (Bhaskar, 2008). • Epistemologically the 'things' are not directly observable (ie., mediated access to the world (Fleetwood, 2005)). • Representational realism (i.e., language represents 'things' and language is 'more trustworthy' than matter). Things in the world are conceptually mediated (Fleetwood, 2005) (in contrast to 'strict' correspondence).	• Relational ontology. • Primary ontological unit is (sociomaterial) phenomenon. • World is composed of phenomena in their differential (sociomaterial) becoming. • Intra-acting agencies are constitutive of phenomena. • Phenomenon have fluid borders that are constituted through material-discursive practices (Barad, 2003). • Epistemologically performative (knowledge-making is a practice (Barad, 2007)).
Matter	• A world of matter exists independent of our construction of it (Bhaskar, 2008). • Matter is assumed to be given, discrete and concrete entities with clearly identifiable boundaries (Leonardi (2013)). • Matter has attributes stable across contexts (Leonardi, 2011).	• Matter is a process of congealing of agency (Barad, 2007) • Matter and social are constitutively entangled. • 'Agential cuts' draw boundaries enacting social/material, nature/culture.
Agency	• Both social (/human) and material agencies that differ only in respect to intentionality. • Agency is an attribute of the entity to act on its own. • Social (human) agency is the ability to form and realize one's goal (Leonardi, 2011, p. 147). • Material agency is 'the capacity for nonhuman entities to act on their own, apart from human intervention' (Leonardi, 2011, p. 148)	• Both social and material agencies ("posthumanist" account) that exists only in relation to a phenomenon. • Agency is the space of intra-active possibilities for (re)configuring the phenomenon • Agency is an enactment in lieu of something someone or something has.
Time and space	• Time is a referential background flowing in evenly spaced individual moments. • Space is a container within which the discrete entities reside. • Events take place in a trajectory over time and space.	• Time and space are entangled as timespace. • Iterative intra-actions are the dynamics through which temporality and spatiality are produced and iteratively reconfigured (Barad, 2010)

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4.

SOCIOMATERIAL ETHNOGRAPHY: TAKING THE MATTER SERIOUSLY

Complete Research

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Abstract

Ethnographic research is a form of qualitative inquiry that creates deep and rich understanding of a studied naturalistic phenomenon. Traditionally, ethnographic research has focused on uncovering the meanings and interpretations of those studied. In other words, ethnographies have focused on uncovering the social construction of the world that reflects underlying interpretive stance. However, recent theoretical developments within Information Systems (IS) and management research emphasize that it is not only social constructions but 'matter' that matters. Research that aims at taking matter seriously in their theorizing are referred to as sociomateriality. Despite that empirical sociomateriality research seems to prefer ethnography as research approach, explicit reflections on the applicability of ethnography for sociomaterialist studies lack. This paper aims at contributing by arguing for the applicability of ethnography for sociomaterialist studies, building especially on agential realist worldview. Applying sociomaterial stance for ethnographies emphasize (1) studying the entanglement of social and material in lieu of social constructions; (2) sensitivity to performativity over representations; and (3) viewing researcher as part of, in lieu of, within, the phenomenon studied. The study contributes to the discussions on sociomateriality by lowering the barrier to conduct sociomaterialist empirical work. Conclusions are drawn.

Keywords: Sociomaterial, ethnography, Barad, field study, worldview.

1 Introduction

'Listen: all this opposition between ‘standpoint’ and ‘view from nowhere’, you can safely forget. And also this difference between ‘interpretative’ and ‘objectivist’. Leave hermeneutics aside and go back to the object—or rather, to the thing' (Latour, 2005, p.415).

Ethnographic research is a form of naturalistic inquiry that emphasizes deep understanding and rich descriptions of a studied phenomenon (Lincoln & Guba, 1985; Myers, 1999). Having its roots in (cultural) anthropology, ethnographic research has traditionally focused on understanding cultures, whether they are societal cultures or organizational cultures (Koskinen, Alasuutari & Peltonen, 2005). Given its original focus, it is no wonder ethnographic research has become associated with interpretive research (Klein & Myers, 1999; Walsham, 1995a; Walsham, 2006; Orlikowski & Baroudi, 1991). Although interpretive research is not a single (philosophical) worldview, central to the worldview, is the emphasis of social constructions over that of the material world. Despite that its original focus and common understanding of applicability of ethnographic studies has been on the social construction of reality, such as cultures, meanings and identities, ethnographic research provides an opportunity to understand the materiality of everyday life from a naturalist, realist perspective that is not interpretive. Understanding the materiality of everyday life is especially relevant for Information Systems (IS) researchers, who study the relation between material apparatuses (Boell & Cecez-Kecmanovic, 2012) and organizations (Leonardi & Barley, 2008; Orlikowski & Baroudi, 1991; Walsham, 1993).

However, during the existence of IS discipline, theorizing the relation between technologies and organizations has swung like pendulum between technological determinism and social voluntarism/determinism (Leonardi & Barley, 2008; Orlikowski & Scott, 2008). In order to theorize the relation in a more balanced way IS researchers have lately focused on a highly theoretical perspective known as sociomateriality (Leonardi, 2011; Leonardi, 2013; Kautz & Jensen, 2013; Kautz & Jensen, 2012; Orlikowski & Scott, 2008).

Sociomateriality research within IS and management literature, draws its insights from a loosely connected group of sociologists and Science and Technology Studies (STS) scholars, also known as 'new materialists' (Dolphijn & van der Tuin, 2012). Central to sociomateriality is to take 'matter' seriously in theorizing. As Barad (2003) argued '[l]anguage matters. Discourse matters. Culture matters. There is an important sense in which the only thing that does not seem to matter anymore is matter' (p. 801).

Past literature suggests that empirical accounts of sociomateriality seem to employ ethnography as their research approach (see Leonardi (2011), Østerlie, Almklov and Hepsø (2012) and Doolin and McLeod (2012) for example). Despite the significant shift in the research focus, from social constructions to taking 'matter' seriously, the empirical research seems to adopt ethnography without explicit reflections on the applicability of ethnography for sociomaterial studies.

The aim of this paper is to argue for the applicability of ethnography for empirical sociomaterial studies building on a philosophical worldview of agential realism (Barad, 2003; Barad, 2007). I readily acknowledge that there are other forms of sociomateriality that are not necessarily based on agential realism (such as critical realism (Leonardi, 2013)). Focusing on agential realism is reasonable as Barad is one of the leading new materialists (Lemke, 2014) and has become very influential in the IS discipline through Orlikowski and Scott’s (2008) work (Mutch, 2013; Leonardi, 2013). Jones (forthcoming), for instance, found 140 articles published in management/IS research since 2007 that all used the concept sociomateriality and almost all of them made references to Orlikowski and Scott (2008) (who built their theorizing on Barad's agential realism). However, I caution, that the particular discussion provided here on the applicability of ethnography for sociomaterial studies, applies mostly to the conduct of sociomaterial research of agential realist nature. The possibility for other authors to study the applicability of ethnography to other forms of (empirical) sociomaterial inquiries is, thus, open. Indeed, the choice made here to focus on agential realism should not be seen as an attempt to limit or exclude other perspectives to sociomaterial research; it is rather a compulsory choice due to feasibility and space constraints.

The paper is structured as follow. First, sociomateriality as philosophical worldview is introduced, centering around worldview of agential realism. The chapter aims at providing sufficient background to appreciate the importance of philosophical worldviews to research inquiries, and to outline those central assumptions embedded in agential realist worldview. Second chapter outlines some of the prior studies in which ethnography have been applied to study sociomaterial phenomenon and that have appeared in top IS outlets. After the discussion on the prior contributions, the implications of sociomateriality for ethnographic studies is outlined, and the prior research assessed based on the described implications. Lastly, conclusions are drawn.

2 Sociomaterial Worldview

Research and philosophy are closely related. The philosophical worldview fundamentally affects the research (Orlikowski & Baroudi, 1991). Assumptions embedded in any philosophical worldview render certain parts of a studied phenomenon more salient than others, and, consequently, they also embed certain blind spots.

The philosophical worldviews can be seen as beliefs one has about the nature of the world (i.e., ontology) and about the way of creating (valid) knowledge of that world (i.e., epistemology) (Chua, 1986; Orlikowski & Baroudi, 1991). Viewing the philosophical worldviews as beliefs suggests they are accrued rather than learned or chosen. This conception, however, expresses some significant deficiencies in the context of scientific research. In the context of our everyday experience, we accrue certain beliefs over time, and those beliefs form the basis of our values amongst others. However, in the context of science, conflating the worldview as synonymous to belief, is slightly misleading. Although one can hardly dispute the influence of the past experience to which worldview one is compelled by, the worldview is more likely to reflect that experience than be a direct result of it. Committing to a certain philosophical worldview is a matter of intensive reading and thinking. The philosophical worldviews are not the same as loosely connected ideas that are referred to as 'philosophising' in our everyday life. Instead, they are comprehensive and complex frameworks of ideas, constructed by the means of cogent and solid argumentation.

As a summary, the philosophical worldviews are cohesive frameworks, that are often well-known, that embody a certain set of assumptions that reflect one's life experience but are not accrued through life experience *per se.*

2.1 Sociomaterialist Critique: Beyond Matter/Meaning Duality

The canonical way for categorizing the philosophical worldviews in IS and management research is based on a duality view of interpretive versus positivism (Orlikowski & Baroudi, 1991; Chua, 1986; Chen & Hirschheim, 2004)[1]. Despite the seeming unity secured by the very duality, each of the two perspectives enclose a number of perspectives (see for instance Cohen (1980) for perspectives categorized as positivism and Klein and Myers (1999) for

[1] Critical research, or Critical Social Information Systems Research (CSISR) (Klein, 2009), is often taken as the third worldview. However, in line with Chen and Hirschheim [2004], as the critical is marginal in IS it is left aside here.

interpretive). As mentioned above, the duality has created intense debates between positivism and interpretive. Where some have focused on defending/promoting a certain view (for instance Klein (2004)), others have been on a quest for uncovering the *tertium non datur* (Stahl, 2007), the non-existing third one. Despite the claimed non-existence, Mingers (2004) has suggested critical realism as a possible bridge to gap the duality in order to form a common philosophical worldview for IS research; pragmatists have argued for discarding the question of worldviews altogether (Rorty, 1982); and 'new materialists', foremost Barad, has argued the whole debate reflects false assumptions embedded in Cartesian thinking (i.e., according to this view Renè Descartes falsely assumed a given internal/external dichotomy) which should be discarded altogether. Due to the scope of this paper, I will not pursue other than Barad's thinking further.

Renè Descartes has been a very central figure for Western thinking. He was a philosopher who lived early 17th century and established what is known as the “new age” of philosophy. Central for him was the clear cut dichotomy between internal and external world; the internal being the mind and the external being the world of material. The dichotomy has hugely influenced thinking since Descartes: the separation between the social and natural (or material); between epistemology and ontology; and between object and subject (Barad, 2007). Central for agential realism is the rejection of this very foundational assumption of a given/fixed/clear dichotomy, accepted at the outset of an inquiry before the inquiry even starts [Ibid.]. It should be, however, said already at this point, agential realism aims not for the complete removal of the dichotomy, but rather emphasizes how the dichotomy becomes/is enacted matters (in both sense of the word). Overcoming the Cartesian dichotomy has large implications for research and for understanding any phenomena.

2.2 The Worldview of Agential Realism

Karen Barad, the figure behind agential realism, has a rather unique combination of research interests; she is a graduate of particle physics and a professor of feminist philosophy as well as a forefront new materialist (the new materialist turn has been greatly influenced by other feminist philosophers as well, such as Judith Butler and Vicky Kirby).

Given her background as particle physicist, it is of no surprise Barad is a naturalist (Rouse, 2004). In order to make the leap and departure from the thinking that has dominated us for centuries, Barad turns to the peculiarities of quantum mechanics. Barad takes the Nobel prizewinner Nils Bohr's physics philosophy as her starting point, but in contrast to Bohr, she does not settle for mere epistemological issues of quantum mechanics but seeks for an elaboration that also encompasses ontology. This philosophical framework is coined as (ethico-)onto-epistem-ology (the parenthesis are mine in order to exclude the 'ethico' part of her framework in order to limit the scope of this discussion) (Barad, 2007).

For agential realism, the world is not 'out there' as individual 'things' or constructed socially, but enacted as practices (i.e., it is performative). Any knowledge creation takes place as part of the world and contributes to the world in its becoming. And science, as a form of knowledge creating activity, is no exception. That is, any research takes place as part of the world and shapes how the world becomes to be, giving rise to questions on accountability. As Bohr has argued in physics, any observation is possible only if the impact of measurement is indeterminate (Bohr in Barad (2007)). This shift has important implications, as the researchers are not seen as external viewers of the world (in the sense of the positivistic/empiricist view), neither are they within the world (in the sense of idealism/relativism view) but active 'agents' as part of the world in its differential becoming.

In order to come up with such a bold claim, Barad (2007) reworks the ontological and epistemological foundations. For her, world is not composed of individual things and their representations, but a world is composed of phenomena and within-phenomena-"components" that are configured (and reconfigured) in a certain way to constitute a phenomena. Individual "components" in the world get their meaning and properties only in relation to other components within a phenomenon (thus the citation marks around "components"). As Rouse (2004) points out, according to agential realism 'world only acquires definite boundaries, and concepts only acquire definite content, together' (p. 146). These a priori indeterminate relations between the "components" are referred to as 'intra-actions' (note the 'intra' rather than 'inter' to signal that no pre-existing relata exists between the components) and they are constitutive of the phenomenon produced. Thus, world is composed of within-phenomenon intra-acting "components" that receive their significance only as part of the phenomena rather than having independent universal properties (i.e., in the sense of essentialism (Fuchs, 2005)).

Within phenomenon, the "components" are active agents, possibly consisting both material and social agents (i.e., it is a "post-humanist" perspective) (Barad, 2007). Her view on material as an active agents that are constitutive of a phenomenon is in close proximity with other relational ontologies such as Actor-Network-Theory (ANT) (see Latour (2005) for a detailed account of the perspective). But for Barad, the agents are not given, i.e., they do not exist as objects-within-phenomenon that await for discovery and representation. Instead, what comes to matter as agents within phenomenon, is a process of enactment, a process of *material discursive practices*[2] that cuts the "components" of the phenomenon as agents of material and social. These cuts, that are epistemic and ontic, are referred to as agential cuts.

2.3 Agential Realism in Ethnographic Information Systems Research

As I have indicated earlier, sociomateriality is a rather late addition in IS research, but has quickly caught the attention of IS scholars (Jones, forthcoming). During the course of this chapter, I will provide some illustrative examples of ethnographic research that has appeared in top IS or management/organization venues and that study sociomateriality building on agential realism.

One of the early examples of ethnographic studies building on agential realism is Nyberg (2009). He studied the enactment of agential cuts between the social and material within the context of call center work. The main method for the creation of empirical material was observations. He paid specific attention how the technologies become cut differently over time as the call center clerks engaged in the practices of serving the customers over the phone and using IT technology as part of their work. Nyberg (2009) observed the meaning and identity of technology are intra-actively produced, emerging *in situ* rather than being stable and fixed.

Schultze (2011) studied the performative nature of identities, agency and worlds through an ethnographic study of virtual world (Second Life) users. Central to her theoretical thinking is the agential realist insights of performative view, rather than fixed and stable representational view, on identity, agency and the world. Through analyzing video recordings of virtual world sessions and conducting interviews, she argued virtual world users engage in a number of discursive and material practices through which the identity, agency and world becomes performed. In other words, identity, agency and world are not clearly cut into that which is virtual and to that which is real, but constructed and changing/shifting through enactments. Schultze (2012) further elaborates the performative nature

[2] As part of her onto-epistem-ology, Barad reworks the notion of 'discursive' practices. It is not possible to elaborate the concept further here, and thus readers should refer to Iedema (2007) for the different uses of the concept, including Barad's definition of the concept.

of especially, identity, arguing the virtual worlds challenge the understanding of embodied identity in the real world, with that of identity as performed and experienced as cyborgism.

Doolin and McLeod (2012) studied boundary objects in IS development project. The focus, the boundary objects, in the study are viewed as entanglements, or assemblages of humans and artifacts that have no inherent ontological separability. Boundary objects thus emerge through the intra-actions of the “components”. The sociomaterial conception of boundary objects significantly transforms the understanding from that of boundary objects as static and fixed entities, mediating knowledge exchange and cooperation, into boundary objects that are (1) only meaningful as part of a certain practice (the boundary objects emerge from specific intra-actions); (2) dynamic and emerging; (3) useful only as assemblages/entanglements, not as separate, individual components; (4) performed differently across different times, contexts, and practices; (5) multiplicity of co-existing and related objects that are 'performed and come into being in specific sociomaterial practices' (Doolin & McLeod, 2012, p.573).

Mazmanian, Cohn and Dourish (2014) studied the reconfiguration of sociomateriality within the context of NASA's space flight mission through a long-term ethnography. Building on the powerful concept of (re)configuration from Barad (2007), the focus of the study was to understand the ongoing and shifting relations between social and material, that is, the processes of reconfigurations. In order to study the ongoing relations, the authors argued for the need of a more careful and closer examination of how the reconfigurations take place. As their focus is on a space mission, graphical repsentations and a multitude of figures constitute the relation between "here" (as in earth) and "there" (as in space). These '[o]ngoing acts of documenting, imaging, and imagining the world—graphically, mathematically, numerically, digitally, physically, organizationally—engender reality through dynamic reconfiguration between and across sociomaterial phenomena' (Mazmanian et al., 2014, p.16).

Lastly, Østerlie et al. (2012) focus on the materiality of knowing through long-term ethnographic study in petroleum drilling context. While they build explicitly on agential realist notion of entanglement, the influence of Barad's conception of material knowing has clearly influenced their thinking. The authors argue, instead of viewing knowing as a material activity (Orlikowski, 2007), a dual materiality is more appropriate conception. The dual materiality of knowing, emphasizes 'how IS becomes important, as its materiality plays an integral part in creating, not simply representing, the materiality of the physical world, in our case, the well flow' (Østerlie et al., 2012, p.102).

2.4 Sociomaterial Ethnography

The sociomaterial stance necessitates expanding the ethnographic method from understanding the social construction of the world into understanding the world as sociomaterial becoming. Three main considerations for the sociomaterial ethnographies apply. First, sociomateriality emphasizes accepting the assumption of constitutive entanglement of social and material (i.e., sociomateriality). Second, sociomateriality emphasis the performative over representational. Third, the sociomateriality situates researcher as part of phenomenon. Table 1 provides an overview of a comparison between interpretive and sociomaterial ethnographies. Next, I will elaborate these.

	Interpretive	*Sociomaterial*
Phenomenon of interest	Social constructions	Sociomaterial entanglement
Type of knowledge	Representations	Performative
Role of researcher	Within phenomenon	As part of phenomenon

Table 1. Comparison of interpretive and sociomaterial ethnography

As the sociomateriality emphasizes the entanglement, ethnographers studying sociomateriality need to pay careful attention not only to the meanings and interpretations, but also how they are material. The informants, are likely to not talk about sociomateriality, but will make clear differences between a material artifact, and a social actor (Leonardi, 2013). But even if the informants do not use the language, it is the theoretical lens through which the empirical material is constructed into meaningful theories about the world. As Geertz (1973) puts it '[w]hat we call our data are really our own constructions of other people's constructions of what they and their compatriots are up to'(p. 9). In the context of agential realism, however, constructs should not be seen as mental constructs, but rather as what Barad (2007) calls descriptive concepts. The concepts are material discursive, in such a way that the concept is a material arrangement of the world, but they are also discursive. Here, the discursive is not the same as discourse or a speech act. Instead, the discursive refers to the conditions for a specific concept to be intelligible. The word hammer is not intelligible unless there is a material construction that is hammer and that the word makes sense within those conditions (for instance, in English speaking context, and where 'hammers' make sense). Thus, in order to accurately conceptualize the sociomateriality of a phenomenon, it is imperative to immerse into the context. The researcher needs to understand the material discursive nature of the context. It is unlikely that such understanding would be attainable through mere interviews, but requires one to immerse into the context of study. Long-term studies using observations are thus appropriate approaches. Further, as the discussion above indicates, the prior research has adopted the long-term approach.

Sociomateriality emphasizes the processual nature of the world. World is in its differential sociomaterial becoming, rather than stable and fixed. Each intra-action reconfigures the world, and new opportunities arise as others are excluded in the reconfiguration (Barad, 2007). The challenge for ethnography then, is to capture and describe the performative nature of the world, rather than its static representations. This is not to indicate interpretive would take its phenomenon to be static. On the contrary, 'interpretive research seeks to understand a moving target' (p. 73). As Barad (2007) and Orlikowski and Scott (2008) underline, sociomateriality is also a semantic issue. The semantic nature is already encapsulated in the very concept of "sociomateriality" that itself, written without a hyphen, aims to signal the inseparability of matter and meaning. However, the move away from representation into performative accounts requires a vocabulary that is of doing. Beyes and Steyaert (2012), for instance, argue for a non-representational conception of space (not as the place outside of earth, but as that which separates). Instead of space, they argue for performative understanding they conceptualize as *spacing*. It is a matter of doing, a matter of performing and thus something which is always in its becoming and never finished. The ethnographic researcher has to understand the happening, which emphasizes being there as part of the happening, but also to adopt a way of writing, a language that conveys flux.

Sociomateriality positions researchers as part of the phenomenon studied. This differs from the interpretive way of seeing researcher as being *within* the phenomenon. The difference between the two views is that interpretive research sees that any observation is 'distorted' by our preconceptions (Klein & Myers, 1999; Gadamer, 2004). The 'distortions', the preconceptions, however, for interpretive researchers are the very condition for understanding, and thus are seen as positive rather than negative (although my use of the concept 'distortion' might suggest otherwise). Due to the reworking of internal/external dichotomy, sociomaterialists have no place for preconceptions as 'internal'. Instead, researchers are part of the phenomenon. They are agents and thus constitutive parts of what they study. However, this does not place the researcher in position in which anything or everything would be possible (Barad, 2007). On the contrary, intra-actions are constraining and enabling and 'regulate' possibilities for reconfigurations (that is, shifts in the social/material boundaries and properties). The possibilities are not, however, fixed, but iteratively (re)configured through each intra-action. Positioning the researcher within phenomenon emphasizes accountability (Barad, 2007). The intra-actions of the researcher matter, and (re)configure the world in its becoming. Thus, ethnographic researcher has to be sensitive to the cuts she/he helps to enact.

2.5 Assessment of Ethnographic Sociomaterial Research

The previous discussion provides the necessary basis for assessing the past literature. The identified differences between interpretive and sociomaterial ethnographies enable to assess whether the past research has considered the sociomaterialist insights in their inquiries. Further, the assessment highlights the way in which these insights appeared in the past literature. Table 2 provides the assessment across the three identified differences. The assessment uses the same literature that was introduced earlier as examples of high-quality sociomaterial research within IS and management disciplines. The assessment is based on those information documented or interpreted from the published articles. Despite that all of the assessed research focus on sociomaterial entanglements in lieu of social constructions, none of the research provides explicit reflections on how the chosen focus influenced the research design. What the authors, however, emphasize is the sociomaterial nature of the phenomenon they studied.

	Nyberg (2009)	*Schultze (2011)*	*Doolin and McLeod (2012)*	*Mazmanian et al. (2014)*	*Østerlie et al. (2012)*
Sociomaterial entanglement or social constructions	Social construction and sociomaterial entanglement. The study aimed at constructing what the author calls as 'customer service call', as a social construction. The study, however, aimed at better understanding of the shifting boundaries constructed by actors.	Sociomaterial entanglement. The research centers around identity as entangled between virtual and real worlds.	Sociomaterial entanglement. The study views boundary objects as sociomaterial assamblages that emerge from human/material intra-action.	Sociomaterial entanglement. As the authors 'emphasize social and material are each simply selective projections of a tangled whole' (p. 2).	Sociomaterial entanglement. The study shows how knowing is not merely a human based activity, but entangled with the materiality of IS.
Performative or representational	Performative. At the core of the study is to challenge static representations by showing the constantly shifting and changing boundaries (the agential cuts) that produce and reproduce multiple human and non-human actors.	Performative. The research questions the taken-for-granted boundary between virtual and real world identities. Instead of static boundary, the research shows how the identities are performatively produced.	Performative. The authors draw on Barad's concept of intra-action to develop a performative account of boundary objects that emerge through the intra-actions, rather than being fixed artifacts/objects.	Perfomative. The study centers on the concept of dynamic reconfiguration. The concept provides sensitivity to the ongoing, shifting relations of matter and meaning.	Performative. The study conveys the performative nature of knowledge, by shifting the focus to *knowing* (as doing) rather than knowledge (as representations of that which is represented).

Researcher as part of or within phenomenon	Within phenomenon. Author spent significant amount of time onsite, during an extended period (8 months), during which he closely monitored the customer care employees. Nevertheless, the study externalizes the researcher as being an interpreter but not as a part of the research. Despite that agential cuts provided the lens for analyzing the shifting boundaries, the author provides no reflections on the implications and accountability for the cuts he himself helped to enact.	Within phenomenon. Despite that the author draws on Barad's concept of intra-action, the research does not provide explicit account on how the researcher intra-acted as part of the phenomenon.	Within phenomenon. Although the concept intra-actions form the central arguments of the paper, the authors do not provide explicit discussion on how the authors intra-acted as part of the phenomenon.	Within phenomenon. The authors themselves engaged in the activities/practices of those who they studied (participant observations). However, they provide no explicit reflection of how they (and their participation) contributes to the world in its differential becoming.	Within phenomenon. The authors make clear distinction between their analysis and the informants. Thus, understandably, no explicit reflections on the part of researchers in the studied phenomenon.

Table 2. Assessment of sociomaterial ethnographic research

In overall, what seems to be at the core of the studies is the ambition to re-conceptualize the phenomena of interest as situated and performed over static, fixed and stable representations; doing in lieu of representation. Further, they move the theorizing beyond the conception of separate entities of social and material into analyzing them as entangled. For instance, the conception of knowing in Østerlie et al. (2012) dramatically questions understanding of what has been traditionally viewed as very anthropocentric concept, knowing (i.e., it is a person, the self, that cognizes and knows), by theorizing it as (dual) material. Lastly, despite that the view of researcher as part of the phenomenon is one of the core arguments in agential realism, none of the assessed research seems to place researcher as part of the phenomenon.

3 Conclusions

The article sought to study the applicability of ethnography for sociomaterial IS studies. The focus was especially on sociomaterial studies that build on agential realist worldview.

The provided discussion suggests ethnographic research is suitable for creating knowledge of sociomaterial phenomena. However, ethnographic studies taking sociomaterial perspective should (1) emphasize sociomaterial entanglements over social constructions; (2) provide empirical accounts that are performative rather than representational; and (3) position researcher as part of the studied phenomenon in lieu of within phenomenon.

An assessment of prior high-quality ethnographic research studying sociomateriality suggests the past research has focused on the sociomaterial entanglements and the performative and temporal nature of the entanglements (aforementioned criteria 1 and 2). The entanglements as temporary and fluid are in a flux, which underlines the importance of studying the phenomenon *in situ* as it unfolds. To this extent, ethnographic research is particularly apt. It allows researcher to immerse in to the 'heat of the everyday' and observe the entanglements of matter and meaning as informants go about their everyday work routines. It is likely that, for instance, through interviews, the flux of the entanglements is less likely to unfold as vividly as experienced *in situ*.

The assessment further suggests, the assessed research has neglected the insight of researcher as part of phenomenon, or at least, has not provided explicit discussion on how the author(s) research practices were a part of what they studied and reported. The lack of the discussion misses two important points of agential realism: (1) how the researchers' work practices are a part of the phenomenon in its becoming; and (2) with what consequences. First, the insight of researchers intimate relation to the phenomenon studied is not new, especially not in social sciences. Already one of the most cited and well-known American sociologist, Anthony Giddens, recognized the 'the dual hermeneutics' that is, the reflective, dual nature of objects/subjects, by arguing it is not merely the researcher who is in the privileged position of the interpreter but is also actively interpreted by those studied. However, this is not to suggest hermeneutics as a way to understand Barad's insight of researcher as part of phenomenon, but to rather indicate the researchers' active role in the becoming of the phenomenon of interest. To appreciate some of the consequences of the insight, it is necessary to look afield from IS. Schadler (2014), based on her ethnographic studies that build on new materialist insights, she argues 'researchers' tools become an apparatus (Barad), which is becoming with a research environment. As a consequence research has its part in the formation of those boundaries, which are researched and in the figurations of the "object", while we study how the object is figured'. In relation to the second important point, agential realism emphasizes the researchers' accountability over the cuts that researchers help to enact which reconfigure the phenomenon in its becoming. To this extent, further research is needed. As a conscious choice, in this research, I have excluded discussions that go to the domain of (research) ethics. Thus, future research should delve into the topic, in order to understand the ethical questions of 'post-humanism' for IS researchers.

The results should be seen as illustrative rather than indicative. The low number of assessed articles limits the possibilities for making more general arguments. As the research here did not conduct a systematic literature review to uncover *all* research that studies sociomateriality, but focused on high-quality examples to illustrate sociomaterial ethnography, it is possible other IS research exists that adopts the stance of researcher as part of phenomenon. However, as the reviewed articles have been published in a top IS and management venues, it is likely they have had significant influence on the way other similar studies have been conducted.

The analysis provided here contributes to the sociomateriality research by lowering the barrier to conduct empirical research that is known to be a challenge (Leonardi, 2013; Mutch, 2013). By identifying those salient aspects that empirical sociomaterial studies should take into account, the researchers are better apt to pay attention and design their research in a way that is truthful to their adopted position.

Nevertheless, ethnographic research provides a compelling and useful approach for building knowledge on organizational and other phenomena, whether the focus is on social constructions or on the materiality of the phenomenon.

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5.

ANALYZING THE RELATIONSHIP BETWEEN WORKSPACE AND SMART INFRASTRUCTURE RELIABILITY AND CONTINUITY: AN ETHNOGRAPHY OF TECHNICIANS' WORK

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Abstract

Ensuring the reliable and continuous operations of complex, unpredictable, and unstable smart infrastructures, such as computerized and automated power grids or water distribution systems, is a persisting organizational challenge and a societal concern. As technologies are inherently unreliable and, especially, the behavior of complex technological systems is unpredictable, the reliability and continuity of such systems cannot be a mere technological concern, but are precarious achievements that require humans, technologies and other actors. Prior research has shown that work creates variance in organizational performance and that reliability and continuity emerges from what work is done and how it is performed. This ethnographic research focuses on technicians' IT enabled workspace to analyze how the materiality of the workspace conditions and enables technicians to perform the reliability and continuity of a smart infrastructure (smart power grid). Building on sociomaterial theorizing and infrastructure studies, a concept of infra-acting is developed to denote the technicians' possibilities for action in smart infrastructure setting, and to foreground and make sense of the reciprocity between the (materiality of) technicians' workspace and infrastructure continuity. Discussion and conclusions are provided.

Keywords: Smart infrastructures, reliability, continuity, sociomateriality, technicians, work.

1 INTRODUCTION

Smart infrastructures, such as computerized and automated power grids and water distribution systems, are the bedrock and backbone of both contemporary organizations and societies. They enable organizations to work and societies to function. Thus their reliable and continuous operation is imperative. Yet, the complex, large scale systems, such as infrastructures, have an inherent tendency towards instability, disorder and decay – towards 'normal accidents' (Perrow, 1981). Moreover, technologies are inherently unreliable (Butler & Gray, 2006). Therefore, the reliability and continuity of the infrastructures can never be achieved through technological improvements only, but require concerted and harmonious actions of humans, technologies and other powerful actors (Bennett, 2005). In particular, often invisible maintenance and repair work is required to maintain the infrastructural circulation even at times the infrastructure appears to work 'normally' (Graham, 2012, p. 19). Indeed, without the often hidden but enormous investments that are constantly put in maintaining and repairing infrastructures (Graham & Thrift, 2007), they would soon cease to function, become obsolete and gradually transform into ruins like the ancient aqueducts that now only remind us of the times of their operation. Without continual maintenance and repair there is no reliability nor continuity, only decay (Ureta 2014).

Reliability of inherently unreliable technologies seems to emerge from what work is done and how it is performed (Butler & Gray, 2006). The work that is put to maintain and repair infrastructures is, however, often invisible and performed in the background but crucial for the functioning of the system (Graham & Thrift, 2007). While such studies show that invisible work is crucial, less attention has been paid to the fact that work is always entangled with materiality (Orlikowski & Scott, 2008). The tools and the technologies we use, the artifacts that structure our environment and action, and the non-humans we mobilize – the materialities of work – both enable and constrain us in whatever work we do. In other words, materiality shapes human action and agency (Barad, 2007; Bennett, 2009), and, thereof, the way in which work is performed (Ashcraft et al., 2009). Particularly, '(a) material place/space influences the resources available for interaction and, thus, conditions agency' (Ashcraft et al., 2009, p. 31). Especially, the integration of IT and traditional infrastructures have opened up new possibilities for maintenance and repair and restructured technicians' work (e.g., Almklov et al., 2014; Østerlie et al., 2012). Consequently, understanding the reliability and continuity of infrastructures entails understanding how work to maintain and repair infrastructures is entangled with the infrastructures' materiality.

This ethnographic research analyzes technicians' IT enabled 'invisible work' to maintain and repair a smart infrastructure (a smart power grid) and focuses on the reciprocity between the technicians' material place/space of work – their workspace – and possibilities to perform the reliability and continuity of the smart infrastructure. Accordingly, it addresses the following research question: how the materiality of the workspace conditions and enables technicians to perform the reliability and continuity of a smart infrastructure (smart power grid)? The theorizing builds on sociomaterial agency (Barad, 2007; Schultze, 2011; Scott & Orlikowski, 2014). As such, this research contributes to the call to study 'the relationship between information, technology, and the changing nature of work' (Forman et al., 2014).

The paper is organized as follows. First, the relation between materiality and action in infrastructure context is discussed and the concept of infra-acting and workspace are theoretically developed as the theoretical foundations of the study. Second, the research approach is detailed. Third, the findings of the study are discussed. Finally, conclusions and discussions are provided that connect the research findings to extant research.

2 TECHNICIANS' WORKSPACE AS INFRA-ACTING POSSIBILITIES

Sociomateriality has emerged in IS as a promising – yet extremely theoretical (Leonardi, 2013) – perspective to theorize the role of materiality in social affairs. We draw on sociomaterial conception of agency (Barad, 2007; Bennett, 2009) to theoretically inform the development of a concept of infra-acting. The concept offers a lens to make sense of the relationship between technicians' workspace, materiality of the smart infrastructures and technicians' possibilities for action.

2.1 Materiality and action

Human action is always entangled with materiality, which shapes it in important ways. As Bennett argues '[w]hen humans act they do not exercise exclusively human powers, but express and engage a variety of other actants [actors], including food, microorganisms, minerals, artefacts, sounds, bio- and other technologies, et cetera' (Khan, 2012, p. 52-53). For example, even a simple task of moving a hand requires mobilizing a plethora of materialities. That is, action is always relational to the material constitution of a phenomenon (Barad, 2007) in such a way that different material constitutions open up different possibilities for action. For instance, a hammer reconfigures carpenter's possibilities for action that are different than possibilities for action without the hammer. What those possibilities are and whether they condition or enable action is relational to the practices and other materialities of which they are a part of; hammering a nail is not only relational to the hammerers' ability or intention to drive a nail, but relational to the nail (bad quality nails tend to only bend when hit!), the substance to which the nail is being hammered to, and so forth. In sociomaterility's terms, 'things' only acquire their definite boundaries and properties in relation to a practice they are a part of (Barad, 2007). Agency, then, is not a property of any individual entity, whether human or non-human, but an outcome of a particular configuration of human and non-human forces (Bennett, 2009). Quoting Ashcraft et al. (2009) '[a]gency is not about determining the attributes of actors, but is instead about the constant (re)negotiation of possibilities, such that material and human agencies keep shaping one another in evolving space and time' (p. 31). That is, the workspace that includes the various materialities as part of the place/space for action shapes the possibilities for action (Ashcraft et al., 2009). While traditionally the technicians' workspace has included such materialities as hammers, screwdrivers, and multimeters, the material constitution of the workspace of technicians working with smart infrastructures is much more complex, distributed and IT-enabled.

2.2 Smart infrastructures and action

Infrastructures, as Graham (2012) argues, are 'complex assemblages that bring all manner of human, non-human, and natural agents into a multitude of continuous liaisons across geographic space' (p. 11). It is as if the infrastructure forms a skeleton that binds together various actors into a heterogeneous amalgam of materialities. As such, the functioning of an infrastructure results from a coordinated and harmonious performance of those heterogeneous actors. As discussed above, this does not imply that all actors would be the same but that their agency is relational to the amalgam of humans and non-humans (Barad, 2007). Yet, they all have the ability to express agency and have an effect for the whole. Human agency is thus not merely a concern of intention or accurate translation of an intention to effects, but a matter of mobilizing and reconfiguring a whole bunch of other actors that do not always seem cooperative. Such a conception of agency appears more true to our everyday experience 'where it seems that one can never quite get things done, where intentions are always bumping into (and only occasionally trumping) the trajectories of other beings, forces, or institutions.' (Bennett, 2005, p. 453).

While infrastructures often evoke images of permanence and rigidity, their constitution may change abruptly as actors enter and leave, or become more and less salient. Indeed, it is the abrupt changes of infrastructures that we often experience as incidents or breakdowns. The seeming and precarious harmony between the parts that form the infrastructure may transforms in an instant into seeming violence between the parts; the infrastructure transforms into a whole where the parts do not seem to thrive towards a common goal. Further, infrastructures evolve and are dynamic (Hanseth & Lyytinen, 2010; Vespignani, 2009), and are never finished (Tilson et al. 2010). Despite their dynamic nature, infrastructures entail certain materiality without which there could not be continuity. This materiality can 'become a palimpsest of developing forms and practices. The continuity of the substrate, although allowing practice to change, simultaneously helps bring the history of practice to bear on the present'.

(Brown & Duguid, 1994, p. 18) This is also what Barad (2007) refers to as the sedimentation of practices of matter's becoming as its historicity. What this implies is that also the materiality of infrastructures sediments the practices of its becoming. While the sedimentation affords continuity, it also creates inertia for change (Venters et al. 2014). For instance, railroad tracks makes it possible for a train to move (and the transportation infrastructure to exist), but once implemented, the tracks are very rigid and hard to change. This also has implications for action, as it is not merely a question of the driver's intentions whether or not s/he will make a turn when the tracks turn when driving the train.

Contemporary infrastructures are not merely mechanical or electrical but also computerized. These smart infrastructures contain 'smart' capabilities that allow remote control, diagnostics, and repair, but also enable the infrastructures to automatically reconfigure themselves and respond to incidents. Roads, for instance, can be monitored from centralized location, certain parts of the road closed, speed limits changed and so forth. In computerized power grids (i.e., 'smart grids'), the IT technologies have even more profoundly changed the technicians' work. Various IT based systems connect and commingle with the traditional power grid that forms a seamless whole that would be very hard or even impossible to discern and dissect into separate IT and power technologies. Many of the components, while they may serve important functions for the distribution of electricity, are in themselves small computers. These technologies create and reconfigure the technicians' world like no other materials. The diagnostics information various sensors provide are responsible for the 'dual materiality' (Østerlie et al., 2012) of the grid and do not merely mediate some existing information but actively create a world that would not exist without the intermingling of those technologies and technicians' practices. The remote control and automatic rerouting capabilities the IT technologies afford, create new scales for space and time. The materiality of IT and technicians jointly perform a reality where location, distance, and time lose their previous significance, as connections and boundaries become more salient than geographic and time measured distances (Barad, 2007).

In brief, material aspects of infrastructures shape the way agency is understood and how infrastructures constrain and enable technicians' possibilities for action. We refer to these possibilities as infra-acting possibilities. Analyzing the technicians' infra-acting possibilities provides a fruitful way for understanding the material conditions under which technicians perform reliability and continuity of a smart infrastructure.

3 RESEARCH APPROACH

Ethnography is one of the most in-depth research approaches that allows constructing detailed empirical material of the studied phenomenon. It is broadly accepted as one of the main research approaches in IS discipline (Myers, 1999), and has yielded highly impactful research on work and technologies (e.g., Orr, 1996; Zuboff, 1988; Barley and Kunda, 2001). Ethnographic studies do not aim for statistical generalizations, but focus on single site and study it extensively to generate deep insights of the phenomenon (Myers, 1997). Therefore, also the research description and findings follow a form of 'thick description' (i.e., a detailed and verbose account of the phenomenon) (Geertz, 1973) – within the given page limit – that aim for veracity and truthfulness of the description in lieu of, for instance, validity and reliability (Guba, 1981; Golden-Biddle and Locke, 1993; Klein & Myers, 1999; Jarzabkowski et al., 2014).

Following ethnographic tradition, the empirical material was primarily constructed through participant observations. The observations took place between October 2014 and May 2015 (2-3 days a week and 8 hours on average, except between mid-December to mid-January). Participant observation is often seen as the epitome of ethnographic research (Ingold, 2014). Through participant observation, researcher is expected to take part in the daily lives of those studied, and gradually and over time build an understanding of the world of the informants. Collecting observations in lieu of, for instance, reading documents or interviewing informants allowed the first author to observe the social and the material aspects of technicians' work in situ rather than reading or listening what the management thinks the technicians do (cf. Orr, 2006). Further, work practices are often so contextualized that informants may find it hard to explain their work when not actually performing it (Nicolini, 2009). As participant observer, the first author 'threw' himself to the empirical site (Chughtai & Myers, 2014) and followed closely the technicians' daily activities. Most of the time, he sat in the operations center from where the technicians control the power grid. In addition, he had several occasions for informal discussions as the informants daily asked him to join the morning coffee breaks, lunch breaks, and afternoon coffee breaks. He also participated to other informal and formal gatherings that took place within and outside the operations center (for instance, training sessions organized for the technicians). He received an unrestricted access to the premises from a 'gatekeeper' (Cook & Crang, 1995) which allowed him to arrive and leave as best fitted to his schedule. While the technicians worked 24/7 in 12 hour shifts, with few exceptions, the first author made observations during office hours. At first, as typical, he encountered some recalcitrance and suspicion (van Maanen, 2011). His presence raised concerns and questions over the motivation and reason for studying the technicians. Despite that he assured for the technicians the motivation was purely scientific, among some, his presence continued to raise occasional concerns and suspicions, even whether he was a 'spy' working for the management. Nevertheless, during the extended observation period, he was able to win their trust. As the author has no formal education neither in electricity nor in power distribution systems, he had to learn the basics during the stay. He actively read publicly available material on the power distribution systems, about their history, legislation, and resilience in order to be able to discuss with the informants with their professional language and to be able to discuss the observations between us. What caused further complexities and steepened the learning curve was the technicians' intensive use of jargon. Most of the concepts were derived from the physics related to electricity, but included also other concepts that seemed to be highly salient, information intensive, and relational to the particular idiosyncrasies and history of the company. For instance, each substation and other important locations in the grid have a name derived from its physical location. While at first, these concepts seemed to be merely labels for the physical locations, we came to learn they embody and communicate a whole bunch of other information for a knowledgeable and experienced recipient. The label carried with it a whole history of the location, the technological equipment and its affordances, the physical location and how to get there, and so on. As such, the concepts provided the technicians an effective way of communicating. Gradually, and after several moments of slight embarrassment, the first author learned the jargon, their habits and their practices. Towards, the end of the stay, several informants commented that he could start working as a technician. While this was clearly a complement and exaggeration, we took it as an indication for gaining sufficient understanding of their 'world' for the research purposes.

The first author took field notes, as the primary method of documenting the observations. The field notes document events that seemed important at the moment of their creation (Jarzabkowski et al., 2014). The field notes reflect a template provided by Schultze (2000). Often, however, when physically at the site, the first author recorded merely short notes with paper and pen that served as memory cues to recollect the moment of their collection. He then elaborated the notes shortly after each site visit (often during the same day). In addition, he was able to collect several organizational documents, such as yearly reports, contingency plans, and standardized operations procedures. Further, we closely followed and collected any news related to power outages in Finland and other information concerning the field (such as legislation changes). In other words, we sought to collect any information that could help to shed light on the phenomenon of interest (Hammersley & Atkinsson, 2007). These observations, informal discussions, and the documents provided us the basis for our theorizing.

Analyzing the empirical material was informed by qualitative data analysis techniques (Miles & Huberman, 1994) which involved noting down emerging ideas and categories during and after the visits to the empirical site. These notes included emerging ideas on the relation between the technicians' work, materiality and the infrastructure continuity. The theorizing proceeded throughout the collection of empirical material and continued afterwards. In other words, these 'processes [of analyzing and theorizing] were not separate from the fieldwork as they continually fed back and impacted on the fieldwork' (Cecez-Kecmanovic et al., 2014, p. 571). After the observation period, we continued the data analysis by looking back at the emerging ideas and categories, but also leaned on the first author's experiences and knowledge gained during the site visits (i.e., on 'head notes' as Schultze (2000) calls them). During the analysis we continued reading theoretical literature, focusing particularly on sociomateriality. By reading iteratively literature and the data, we began to form an understanding of the phenomenon (Klein & Myers, 1999). Thus, the data analysis included simultaneously both, theoretical as well as empirical development of our ideas. From these iterative cycles, we gradually began to see certain patterns. The patterns resulted in three aspects that we found explanatory of the relationship between the materiality of technicians' work and infrastructure continuity. For instance, during the analysis we identified 'rigidity', 'material resistance', 'inertia', and 'history' as potential categories, but assimilated them as one since they all seemed to contribute to the same 'story'. In the end, to put it short, the historical materialization of the grid, the openness and dynamic presence of other actors in the constitution of the grid, and the inherent unreliability of action in relation to the grid emerged as plausible and truthful abstractions and explanations of the phenomenon. These three aspects will be elaborated next.

3.1 Empirical site

CityGrid Co (a pseudonym) is one of the largest power distribution companies in Finland (based on the number of subscriptions). It operates mainly in the area of one city, but its network extends also to broader area that covers some rural areas and archipelago. It is also one of the oldest power grids in Finland, dating back to the beginning of 20th century. The extensive history is reflected in the grid. Some of the cables still date back to as far as 1950s, and the grid contains a very heterogeneous mixture of old switches, relays and other mechanically operated devices that now operate in contemporary setting but also latest modern digital technologies that automate recovery and configuration tasks. By integrating internet protocol (IP) based control and diagnostics systems to the old mechanical switches, the devices have been updated to meet the needs of the contemporary power grid. The company has been able to perform highly reliably and produce a steady flow of electricity to its customers (2015 the average downtime per subscriber was under 10 minutes).

The grid is managed from a centralized location that was enabled by the technological advancements as in the beginning the grid had to be managed in such a way that each substation was populated by two or more technicians in oil and dirt stained white collar shirts and dark suits that used to be their normal work outfit. There is no single system that would cover all the technicians' tasks but a range of systems of which the supervisory control and data acquisition (SCADA) and distribution management system (DMS) are the most central ones. These two systems (in addition to email and similar office systems) forms the technicians' core 'tools'. Where the SCADA enables them to control, configure and monitor the status of the substations, the DMS provides them a geographic information system, and work flow management system that enables the technicians to coordinate the field technicians, have an overview of the current configuration of the grid, and structure their routine maintenance and repair work through pre-planned operations procedures. It also enables the technicians to simulate the impact of configuration changes to the grid's overall performance and configuration. Other important 'tools' the (local) workspace includes are the (IP-based) telephones; a separate and designated communication network for the society's critical functions; paper copies of the planned maintenance work; Closed Circuit Cameras (CCTV) on the substations; a separate workstation for internet access (physically isolated from the grid's control network); and a system to control the (physical) access to all premises. Figure 1 illustrates the technicians' workspace (to preserve anonymity, the technician is not shown in the figure).

Figure 1. Technicians' workspace (authors' own).

The technicians work to create affordances for others to work (Barley, 1996). Thus, what happens behind the scene as the invisible work and how the affordances are created is significant for all IS work. As Graham (2012) argues, 'digital media use continues to have an aura of transcendence, as though the "virtual" world exists in a completely separate sphere from the messy materialities of the "real" one'. Instead, by focusing on the 'messy materialities', 'we can begin to 'see' 'cyberspace' for what it is – not an ethereal domain of 'virtual' bits and bytes, but a gigantic, materialized and electrically powered system requiring massive amounts of continuous and concerted maintenance and repair' (Graham & Thrift, 2007, p. 13). As such, by focusing on the work of the technicians we may learn a great deal about how the reliability and continuity of smart infrastructures are performed, but also to remind us of the tight connection the production of continuous electricity has to reliability of other ISs that would cease to function in an instant without electricity (but also without which the production of electricity would become difficult or even impossible). Thus, the power grid provides an interesting and important site for this study.

4 FINDINGS

In contrast to what seems to be the general perception, the infrastructures require constant and repeated cycles of maintenance and repair. These practices of maintenance and repair serve as 'normalizing' practices (Ureta, 2014) that seek to sustain, and return, when needed, the system to its 'normal' state. The smart grid too, has a designed normal state that is calculated to be the optimal state for the grid. The optimal state balances between economic calculations, operational requirements, and grid performance. Often, there is a conflict between the optimal economic performance and the optimal configuration for operations[1]. Further, as the technicians explained there is nearly always a gap between the optimal and the current running setup of the grid due to various exceptions caused by ongoing maintenance work or other changes. As such, the exceptional state seems more normal than the 'normal' state.

[1] The conflict between economic interests and optimal operational configuration of the grid is a complex matter and involves various factors that are not feasible to fully cover here. One of the central conflicts concerns the route through which the electricity is carried across the grid. For instance, while certain paths may provide better possibilities to remotely control the flow of electricity and provide redundant paths, if the path is longer it may be less feasible economically as long physical distances attenuate electricity and induce costs as larger proportion of the electricity is 'lost' during transmit.

Despite that technicians populate all public spaces, and the soundscape of urban cities is filled with sounds of maintenance and repair work, the technicians often go unnoticed (Graham & Thrift, 2007). Some of this work that used to be messy, laborious, and even hazardous has, due to the technological advancements, become hygienic and comfortable office work. Despite these advancements, there is still aspects of maintenance work that require field workers and their physical presence at the site. These field technicians form a salient part of the work that is put to ensure the continuity of infrastructures. Through IT enabled coordination of their activities, the field workers become an integral part of the technicians' workspace and jointly construct and extend each other's' possibilities for action.

4.1 Technicians' work at the CityGrid

The technicians' work consists of preparing upcoming maintenance works, coordinating and performing planned work, and responding to any unexpected, befallen events. All the maintenance work has to take place in such a way that it has only minimum impact to the provided service as '[d]ue to society's dependence on infrastructures, stopping them for maintenance or reconfiguration is seldom an option and operations must always be done in the context of the aggregated history of earlier operations' (Almklov & Antonsen, 2014, p. 480) As a general principle, the technicians always seek to minimize the impact of the maintenance work to customers. Thus, any maintenance work requires careful prior planning and preparation of plans. The preparation of the plans include documenting the required configuration changes, appointing resources (both, human and non-human materials such as certain types of vehicles), and verifying the feasibility of those changes to the grid. Each plan is documented using a locally standardized language that affords documenting the required procedures in unified, simple, and short manner. For instance, the plan might include a procedure "OPEN switch Location X towards Location Y". After finishing, the plans are verified by another technician who virtually simulates it and approves it or suggests changes. The maintenance work is then carried out according to the plan and when planned. By structuring the technicians' actions, the documented procedures provide material guidance for the maintenance operations that would at first seem to render the technicians work into mindless rule-following. However, this assessment is far from the truth. As Suchman (2007) has convincingly shown, such plans are not basis for action but rather function as 'informational' sources for action and require technicians' constant awareness. Often, certain maintenance operation may not be possible due to aggregated history of earlier maintenance work that is taking place simultaneously in the grid that might not have been estimated when planning. Deeming the feasibility of changes requires the technicians to be constantly mindful of the overall state of the network that they co-create with the DMS. Occasionally, there is a conflict between the reality the technicians construct with DMS, and the technicians' prior knowledge, which often requires physical visit and visual verification of the equipment by the field technicians to resolve. Further, despite the peer review to verify the plans, the plans occasionally contain mistakes or the maintenance situation might differ from the planned which requires in situ adjustment and, often, co-creating new course of actions with the field technicians or with other technicians working at operations center.

Periodically and unexpectedly, the work is disturbed by alarms the systems generate or by phone calls from important customers, construction workers, or customer care that reports potential problems. These system alarms and phone calls create a hectic and slightly chaotic soundscape to the operations center that can be, at times, stressful. However, each sound carries a specific meaning that alters the technicians' reaction to it. Most importantly, the system alarms for different events varies depending on the severity of the alarm and can be used to infer its severity without reading the actual alarm text. An alarm that is determined important, surfaces emergent behavior and practices that are not visible during other times as the technicians promptly start uncovering what has happened, where it has happened, and why it happened. While the technicians are often able to narrow the impact of the incident or fix it in such a way that the flow of electricity continues to all subscribers, repairing often requires mobilizing the field technicians.

These continuous maintenance and repair practices pace the technicians work day and give raise to reliability and continuity of the smart infrastructures. However, the materiality of the grid, in important ways, regulates the technicians' space of action and change by shaping their workspace. As such, there is no fixed timeframe or a period to describe, no trajectory to outline, but rather to describe what takes place between punctuated moments of organizational change by focusing on the everyday and the normal rather than on the exceptional. The following vignettes are thus illustrative rather than comprehensive that serve to illustrate the reciprocity between materiality of workspace and technicians' possibilities of performing the reliability and continuity of the smart infrastructure.

4.2 Working with and around the legacy

Central for the technicians' work with the smart grid is that their workspace is a setting to which they are 'thrown' into, where the grid's materiality brings past to present as a legacy of the history. By being thrown into means the grid is not build afresh for the (or by the) technicians for optimal and reliable performance, but the technicians have to work with – and sometimes around – that which is given for them. The history that is brought to present by the grid's materiality sediments decades of design decisions, and construction, maintenance and repair practices that all reflect certain aspects of the political and economic landscape of the time of their performance. As Vespignani (2009) has argued, even infrastructures that are often thought as carefully designed, such as road and power infrastructures in cities, evolve dynamically when analyzed over longer periods of time due to such factors as the designers' relative shortness of time perspective. Due to the long history of CityGrid's smart infrastructure, the grid also sediments design decision and materialities that date decades back. The most visible reminiscent of the past design decisions and past political and economic landscape are the grid's cables that carry the electricity. Some of the wires and cables date back decades (even as far as 50-60 years ago). The phenomenal generativity of electricity has generated services and infrastructures that nowadays power all aspects of modern life and societies that were certainly unimaginable when the grid was built to power light bulbs. The increased demands and the sunken cost of ground cabling has meant that almost all new connections are dug underground, whereas all the older parts of the grid use air wires hanged to utility poles. Powering the light bulbs was not as critical as powering, for instance, contemporary IT server facilities or cloud computing farms. The criticality, and economic rationale, also guided the design and implementation practices in such a way that often the best route for the air wires was the shortest route and not the route that would provide optimal reliability. This also meant the air wires would go through forests and other terrain that would leave them easily exposed to trees and other externalities to intervene with the power distribution. While some of the air wires are being changed into ground cables gradually, there are parts of the grid that will not be changed anywhere in the near future due to economic calculations. The development of the grid is thus better described as an evolution than an accurate representation and implementation of some master plan. Further, in addition to the cables and wires, at any given time, the grid embodies technical components of which some are old, some newer, and some new. As such, the grid is not a homogenous entity but a heterogeneous mixture, an amalgam of contemporary IT, decades old mechanical switches and relays, temporary patches that have become permanent, and workarounds to name a few. This historical legacy also structures the technicians' workspace and their infra-acting possibilities. To meet the contemporary demands, CityGrid has invested in automating the grid and in enhancing the remote control of the grid. The grid has been worked iteratively to support these new capabilities, which has meant installing new devices and enhancing old devices by embedding new technologies. One such simple solution includes integrating remotely controllable electronic motors to mechanical switches, giving the technicians an 'extended arm' to turn a lever at a distance within milliseconds for an operation that used to take tens of minutes for a field technician to perform. Thus, the technicians' work has become reorganized and their workspace extended through these simple technologies that perform new realities in which they have to operate. This reorganization of their workspace has also improved the reliability and continuity of the grid by enabling them to work around the some of the legacy implications for reliability. In the case of an outage, for instance, when a tree falls on the air wires and launches the grid's automatic protection mechanisms that shuts down the flow of electricity from the circuit, the technicians may reroute the electricity through another circuit instantly. While removing the fallen tree requires the field technicians' physical presence, by reconfiguring the technicians' workspace, the technologies allow the technicians to remediate the situation, or at least, narrow the scope and impact of the incident. The technicians' actions thus never take place in isolation or as individual actions but are part of and relational to the historical stream of actions that took place before.

4.3 Working with humans and non-humans

While the technicians are physically located in operations center, the materiality of technology extends their workspace much beyond their physical location. The technicians' workspace is no longer tied to local and to that which is on the reach of an arm, but reconfigured and extended through technologies. On the one hand, the materiality of technology creates different conceptions of space and time as through their materiality, the technicians are able to reach even the furthest corners of the grid with just few mouse clicks and perform operations at distance. This is not to imply that the technicians would feel connected to those switches and other equipment at distance in the same way as they are connected to, for instance, the keyboard at the operations center neither does it imply that the technology would somehow bend the time/space continuum nor create wormholes to it. Rather, the materiality of technology gives raise to different kinds of realities that would not exist in the absence of those technologies. In these realities the local and distant lose their previous designation, as those events that are (physically) distant have locally felt effects. The observations showed that while the technicians physically located at a single location much of their work happens at distance and involves mobilizing numerous other actors. As such, it makes sense to not only consider the local space as technicians' workspace but as the smart grid that has both local and non-local aspects. It seems the materiality of the grid creates a fabric that binds together the various actors and forms common foundations for the agencies to operate. However, the constitution of agencies, due to the openness of the power grid is not static but evolves dynamically. This dynamically changing and shifting constitution of agencies shapes in important ways the infrastructure as the technicians' workspace. As Graham (2012) argues, '[w]hile they [power grids] include humans and their constructions, [they] also include some very active and powerful nonhumans: electrons, trees, wind, electromagnetic fields' (p. 11). Indeed, technicians' work unfolds as part of this dynamically changing and shifting amalgam that is populated with other powerful actors that contribute to framing the grid's operation and the technicians' workspace. Simultaneously, however, the technicians would not accomplish much without mobilizing these actors and working with them. The challenge for the technicians to perform is that they are not solely in control of what takes place in their workspace. Based on discussions with the technicians, most often their work is affected by three other actors: careless excavators, pesky critters, and heavy winds. While those are not the only ones, they seem to be the most common and salient 'intruders' in the technicians' workspace that the technicians have to work with. While the strategies to work with each type of actors varies, one strategy is to utilize the electricity itself to solve the incident. Occasionally, as observed, a sudden sound of an alarm draws the technicians' attention, and the colors of the topography of the grid shown by the DMS change abruptly (a line representing a physical wire turns white on the display). Before the technicians are able to react, the grid reacts in milliseconds by reconnecting electricity back to the faulty part in an attempt to restore the electricity. If the electricity could not be restored, the technicians wait for around ten seconds before enacting command that attempts to restore the electricity. If restoring the electricity still fails, the field technicians will be dispatched, and the technicians at the operations center study alternative ways to route the electricity. However, after few minutes the technicians may try again to connect electricity to the faulty part of the grid. The waiting time plays a crucial role, as restoring electricity too promptly would overheat the protective devices or even melt them. Thus, the materiality conditions the technicians' ability and the frequency at which the operation can be performed. While these repeated attempts may sound irrational, what actually happens is that the technicians mobilize the electricity in an attempt to repair the problem. As brutal as it may sound, when the outage is caused by a critter or some other animal that has climbed or flown to the exposed components of the grid, the electrical current electrocutes the animals, and their bodies (or what is left after being electrocuted) may get stuck on the components. By attempting to reconnect the electricity, the electricity may combust the corpses which may then burn and drop away from the line.

4.4 Working with invisibility, complexity and uncertainty

When functioning, the infrastructures seem to become 'invisible' and withdraw to background and only surface on breakdowns (Star & Ruhleder, 1996). This invisibility of the infrastructure also characterizes the work of the technicians. What they know about the infrastructure, how they know it, and when they know it are largely dependent on the technicians' information systems, and other actors. Even the electricity itself, flowing in the cables and through various switches, relays, valves, and so forth is not visible per se but only expressible in quantified metrics (e.g., in watts, amperes, volts). Thus, 'knowing' the electricity would be impossible (and unquestionable a hazardous attempt) without the sensors that co-create this information together with the technicians and the information system. In such a way, through their joint agency, the electricity, the sensors, the information systems and the technicians jointly construct and give raise to realities that would not exist in the absence of the social or the material. As the technicians expressed, the grid's complexity surpasses any single technician's comprehension, and always contains an element of surprise. The grid embodies certain unpredictability which seemed to be a source of stress and anxiety for the technicians even to such extent that in the past some technicians had changed the work. Thus, the concern is not so much theoretical of whether the behavior could be known in principle but whether it is known or can be known in practice. The unpredictability also animated the grid giving it *geist* and agency to seemingly act on its own. The technicians seemed to accept that when working with such a large scale system the behavior of that system exceeds their control. Experiences from the past have shown that 'anything' can go wrong, as the technicians expressed their view. However, this inherent unreliability and uncertainty importantly shapes the technicians infra-acting possibilities. As described above, the constitution of the grid is always dynamically changing. But in addition to the aforementioned reciprocal and mutual shaping of actors and possibilities, it seems the possibilities do not exist prior to their enactment in practice. This is most visibly projected in technicians' actions when intentions do not translate as expected results. When observing, on several occasions, despite the technicians attempts to reconfigure the grid in order to respond to an emerging incident, the grid would not perform the requested operation. While in some occasions it was possible for the technicians to construct a posterior explanations of what went wrong, in other occasions the technicians merely had to acknowledge the grid works in mysterious ways. Especially, during an incident in the power grid, the unpredictability profoundly shapes the technicians' workspace and alters their possibilities to perform the reliability and continuity of grid. An unsuccessful attempt, a failure to perform a command at distance reworks their infra-acting possibilities. In an instant, what seemed to be near and within the reach of the mouse click becomes desperately distant.

5 DISCUSSION AND CONCLUSIONS

This ethnographic study aimed to investigate the relationship of work and materiality in the context of infrastructure reliability and continuity. To study the relation study builds on sociomaterial theorizing and on the conception of agency to explicate the implications of workspace to continuity and reliability. Sociomaterial theorizing proved fruitful to foreground the ways in which material forces intermingle with, interfere, and condition the social world that would not have been possible when focusing merely on social aspects of work. Building on the sociomaterial conception of agency, the concept of infra-acting was developed to denote and study the relationship between infrastructures and action in order to make sense of the technicians' workspace in smart infrastructure setting. The study contributes to earlier discussions that view technological reliability and continuity as performed in practice (Butler & Gray, 2006). More broadly, the study contributes to the call to study the relationship between technologies and work (Forman et al., 2014). Next, the contributions and implications of the research are elaborated and abstracted towards more general discussions.

This study asked 'how the materiality of the workspace conditions and enables technicians to perform the reliability and continuity of a smart infrastructure (smart power grid)?'. The findings of the study (see Table 1) suggest that the technicians' possibilities to perform reliably is conditioned and enhanced by the materiality of the smart infrastructure. This recognition has significant implications to understanding reliable organizational performance by arguing that in the infrastructure setting human-centric views that focus solely on the social or cognitive processes to explain reliability do not suffice. As the findings indicate, the technicians' work is shaped by non-local aspects of work and that the material forces influenced the technicians' possibilities for performing their work. Omitting material aspects of work when considering reliability and continuity of infrastructures risks overshadowing other salient factors and overemphasizing the role of the technicians as individual actors. Instead, the study suggests that their performance is relational to the infra-acting possibilities of their workspace. The findings indicate the historical legacy that the grid carries can explain some of the variation of how the technicians perform. That is, the way in which the infrastructure has materialized influences how the technicians can perform its reliability. In addition, especially in open and exposed infrastructures, as the power grid at CityGrid, other human and non-human actors shape the infrastructure as the technicians' workspace. Further, break downs in complex technological systems are part of their 'normal' mode of operation (Perrow, 1981), and they always depict a degree of unpredictable and uncertain behavior (Butler & Gray, 2006), due which the outcome of an action cannot be known for sure before the enactment of that action. Taking into account the materiality of infrastructure does not mean that the technicians are irrelevant, but that their actions needs to be placed within the wider material constitution of infrastructures. However, by recognizing that agency is distributed and not solely a property of humans suggests that reliability and continuity studies should focus less on designating responsibility, or even blame, to individuals (or to human collectives), and instead focus on discerning the webs of actors and forces that affect situations and events (cf. Bennett, 2010).

Finding	*Relation to extant research*
Technicians' possibilities to perform the reliability and continuity are conditioned and enhanced by the materiality of the smart infrastructure which frames their workspace.	Extends research on how technological reliability and continuity are performed in practice (Butler & Gray, 2006).
Technicians' workspace entails and is shaped by both local and non-local constitutions of the smart infrastructure.	Support previous findings that that work in infrastructure context has local and non-local aspects (Almklov et al., 2014). Extends research by arguing that 'local' and 'non-local' are not given but created in practice.
Technicians' workspace is conditioned by the historical legacy of the smart infrastructure.	Extends Almklov and Antonsen's (2014) concept of 'historical continuity of operational work' in the context of a smart infrastructure. It extends Venters et al. (2014) by arguing that material legacy creates inertia to technicians' work but it can be worked around by smart technology.
Invisibility, uncertainty and breakdowns of the smart infrastructure characterize technicians' workspace.	While unreliability and unpredictability of the infrastructures is widely known (e.g. Perrow, 1981; Graham, 2012), its relation to technicians' work in maintaining the reliability and continuity of the infrastructure has been less understood.

Table 1. Findings and contributions of the study

Leaning on the sociomaterial theorizing enables to account for the non-local forces and abandon a user-centric view on action which was necessary to appreciate the reliability and continuity challenges the technicians face. To this end, the research suggests that understanding of 'workspace' needs to be reconsidered. The concept of infra-acting provides a way to conceptualize the reciprocity between the dynamic material constitution of infrastructure and action, and thus provides an alternative way for understanding the technicians' workspace. From this perspective, the workspace is not merely that which is in the reach of an arm, but relational to the material constitution of the workspace that creates technicians' realities. As other studies have also asserted (Almklov et al., 2014; Jonsson et al., 2009), in infrastructure context non-local effects may have local causes.

This study also underlines the importance of infrastructure design to be mindful of the technicians' work. The challenge here is that the smart infrastructures have often developed over long periods of time and evolved dynamically rather than along some predetermined trajectory (cf. Hanseth & Lyytinen, 2010). This was also what the technicians at CityGrid were experiencing. The smart infrastructure the technicians at CityGrid work with, the workspace of their work, is not a result of any single design plan, but has resulted through its long history and is 'given' to technicians by the past. As it would be unfeasible to assume that the infrastructure could be built from scratch, the design has to focus on enhancing and extending the existing workspace in relation to that which already exists. That is, the power grid can be worked iteratively by building onto existing rather than building completely anew. Indeed, by integrating IT technologies and mechanical and non-IT technologies, the power grid at CityGrid had been reworked iteratively to incorporate the 'smart' functionalities. Here IS researchers can have an important role to play. As IT technologies are populating areas where they have not existed earlier, the task is to determine ways in which to build information systems on existing (material) infrastructures. This requires increasing our understanding not only on embedded systems but embedding those embedded systems and their technological capabilities to existing, traditional infrastructures to enhance and enable 'smartness' through techniques such as 'Internet of Things'.

More broadly, the research provides an empirical case of the changes smart infrastructure brings to technicians' work. As such, the research contributes to discussions showing the implications of infrastructures to work (e.g., Almklov et al., 2014; Østerlie et al. 2012; Jonsson et al., 2009). The smart infrastructure at CityGrid enables the technicians to perform operations that traditionally would have required technicians' physical presence, such as rerouting the electricity or performing other control operations. This paints a different image of the technicians work and tools as we have traditionally viewed them (cf. Orr, 1996; Barley, 1996). In the CityGrid's smart infrastructure, the IT has profoundly entangled with the technicians' work and the power grid. As we have sought to show in this research, the entanglement gives rise to a new types of workspaces and new forms of realities that would not exist in the absence of the technologies.

Lastly, limitations apply to this research. Most central limitation concern the generalizability of the findings. The study did not sought to make statistical generalizations, and thus, it should not be viewed as a limitation of the study per se. However, by focusing on the single empirical site, the findings are neither directly applicable to other settings nor representative of any population or sample. By relating the findings to more general and abstract theoretical constructs, the research findings could be generalized from particular to theory and related to existing body of knowledge (Lee & Baskerville, 2003). As such, the research extends the existing body of knowledge with one particular study. Nevertheless, the theoretical conceptions brought forth here, may provide useful lenses to study the relation of work and infrastructures also in other settings.

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6.

Entanglement of Infrastructures and Action: Exploring the Material Foundations of Technicians' Work in Smart Infrastructure Context

Completed Research Paper

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Abstract

This study explores the mutual constitution of materiality and action in smart infrastructure context by focusing on technicians' IT-enabled work with complex, distributed, and inherently unreliable smart power grid. Past research suggests infrastructures form a context and a topic unlike the dyadic interaction of humans and computers, and have provided accounts of the ways in which the smart infrastructures shape technicians' work. This study develops a view of agency in smart infrastructure context in order to increase understanding on materiality of action. A concept of infra-acting is brought forth that situates action as part of (the material constitution of) infrastructure. Infra-acting posits that performing actions as part of infrastructures are (1) conditioned by material history; (2) dependent on mobilizing actors; (3) shaped by invisible and dynamic actors; and (4) riddled by vagaries. An ethnographic research provides an empirical illustration to foreground technicians' actions corollary to the materiality of infrastructure.

Keywords: action, agency, infrastructures, sociomateriality, Barad, entanglement, continuity

Introduction

In contemporary organizations and societies nearly everything we do depends on infrastructures; power grids carry electricity that powers our modern technologies, buildings form our office spaces, network infrastructures enable our communications and so forth. As complex, distributed, yet tightly interconnected, and inherently unreliable (Perrow, 1981; Bennett, 2005; Graham & Thrift, 2007) amalgams that are constituted by humans, technologies, and other actors (Bennett, 2005; Graham, 2007), infrastructures profoundly shape the ways in which work unfolds by shaping the possibilities for action. Understanding and explaining how practices and actions emerge from context is a key concern for IS research (e.g., Orlikowski, 2000).

Infrastructure studies in IS have shown that redirecting our gaze from isolated technologies into complex and heterogeneous amalgams of infrastructures (Monteiro et al., 2014; Tilson 2010a;b) trouble many of the conceptions and wisdom of the field by showing the insufficiency of our design approaches (Hanseth & Monteiro, 1997; Star & Ruhleder, 1996; Hanseth & Lyytinen, 2010), governance models (e.g., Ciborra & Hanseth, 2000; Constantinides & Barrett, 2014), and ideas on innovations (Monteiro et al., 2014; Pipek & Wulf, 2009). In addition, scholars have started to explore infrastructures as a context for practices and IS use to understand the ways in which they 'infrastructure work' (i.e., constrain action) and allow 'work of infrastructuring' (i.e., afford action) (Aanestad et al., 2014). These studies have shown that infrastructures enact new realities and enable practices that give raise to 'new frontiers of work' (Forman et al., 2014) such as new forms of nomadic work (Mark & Su, 2010), and virtual work (Wilson et al., 2008). However, infrastructures have had perhaps the most profound impact on technicians' work.

By combining IT technologies, sensors, and other IT-based technologies with mechanical and electrical technologies, 'smart' infrastructures have transformed what it is to be a technician, what work they do and how they perform that work (e.g., Jonsson et al. (2009); Pollock et al. (2009); Østerlie et al. (2012); Almklov et al. (2014)). Examples of such changes are plentiful and vivid as the smart capabilities have widely pervaded the technicians' work: changing road signs and closing roads remotely, rerouting the flow of electricity with a click of a mouse, monitoring flows of oil in real-time hundreds of meters underground, diagnosing break downs from a distance, and so forth. The technicians and the technologies that constitute the smart infrastructures have entangled (Almklov et al., 2014) to such an extent that it is difficult or even impossible to discern them as distinct parts or components of work. Instead, the work 'rests on the materiality of the technology' (Jonsson et al., 2009, p. 250) that does not only mediate some existing information and reality but creates information and performs realities (Østerlie et al. 2012; Almklov et al., 2014). As such, when working with the smart infrastructures, the 'technicians' competencies become pervasively entangled with the new materiality' (Jonsson et al., p. 250). Smart infrastructures form a context and a topic for work and action that deserves closer rumination (Constantinides et al., 2016).

While the technicians' work on smart infrastructures rests on the materiality of digital technologies, it is also anchored to the messy, rigid, and persistent materials—to the copper cables, the paved roads, the rail tracks, and so forth. The smart infrastructures are situated on the cusp of the virtual and the physical. In these settings, the infrastructures form a linchpin in which actions and actors entangle across the physical and the virtual spaces (Almklov et al., 2014), and where effects are not accountable to *a* cause but to a cascade of causes (Bennett, 2009). Consequently, also the concept of 'action' becomes troubled and loses its designation and meaning as a property of the (human) individual and, instead, emerges in the material networks of infrastructures where causes nor effects need not to be 'local' and actors need not to be solely humans. The challenge for the technicians is to work with (and sometimes around) the materialities of these infrastructures under evolving organizational and societal demands of which power grids are a prime example. What used to be the intercity lightning systems (Hughes, 1993) have transformed into massive and complex interconnected systems (Bennett, 2005) that power nearly all aspects of our contemporary life which has significantly shaped the expectations of the public for technicians to ensure reliable and continuous flows of electricity. Under this constant and increasing pressure, the possible ways in which the technicians' work unfolds is within the space of possibilities afforded by the materiality of the infrastructure. As such, it becomes imperative to understand the conditions under which the technicians work and seek to meet the organizational and societal goals.

In this ethnographic study (Myers, 1999), I will explore the technicians' work in a centralized operations center of a smart infrastructure (smart power grid) and focus specifically on the relationship between materiality and action. The purpose of the study is *to uncover the underlying mechanisms that 'infrastructure' (Aanestad et al., 2014) technicians' action to increase understanding of the ways in which the infrastructure shapes technicians' work*. The smart power grid provides a robust empirical basis for the study as an example of technology-enabled work that is entangled with heterogeneous and various materials and actors that constitute the grid: mechanical and electronic switches, relays, cables, electric poles, end users, regulators, wireless communication links, fiber optic connections, mobile devices, substations running embedded Linuxes, control and diagnostics information systems, integrated customer management and fault reporting systems, and so on. I draw on sociomaterial and ontological conception of agency (Barad, 2007; Bennett, 2009) that is particularly useful for studying this type of work that is entangled with materiality and spans beyond the local setting (Almklov et al. 2014; Østerlie et al., 2012; Mikalsen et al., 2014). Building on the field work and on Karen Barad's (2007) concept of intra-action, I propose a concept of *infra-acting* that underlines the material and distributed nature of action by situating action as a part of the materiality of infrastructures (i.e., entangled with) rather than within or outside of it. I argue that infra-acting provides an explanatory lens that is an extension to human-centric notions of action and particularly suitable to explaining emergence of practices in smart infrastructure contexts.

The article proceeds as follows. First the concept of infra-action is developed by building on existing literature on sociomaterial agency and on infrastructures. Second, the methodological details of the ethnographic research approach are outlined. Third, the findings of the study are discussed by presenting examples that are illustrative of the mutual constitution of materiality and corollary (manifestations of) actions. Last conclusions are drawn.

Infra-acting: Situating Agency as Part of Infrastructures

The concept agency has intrigued sociologists and the like for decades, and formed one the core concerns of debates. While conceptions of agency have shaped IS research in important ways (DeSanctis & Poole, 1994; Jones & Karsten, 2008; Orlikowski & Robey, 1991; Orlikowski, 2000), it has been surprisingly rarely at the locus of attention (Rose et al. 2005; Orlikowski, 2005). Instead, it has provided means to understand and explain other IS related phenomenon; a means to an end rather than end in itself. In this chapter, the relation between agency and materiality is develop further as it seems to warrant foundations to start understanding relation to and with materiality as encountered as part of infrastructures. Thus, comprehensive and complete review of discussions and developments of agency is omitted due to feasibility and scope of this project. Instead, the discussion focuses on the concept of infra-acting that situates agency as part of infrastructures. The concept of infra-acting emerged from the interplay between the empirical material and the literature on sociomaterial agency. I will here merely outline the broad theoretical conceptualization of it and, after outlining the research approach in the next Chapter, illustrate the concept with more detailed examples derived from the empirical material.

Historicity and sedimentation of practices

In their seminal and widely influential article on infrastructures, Susan Leigh Star and Karen Ruhleder (1996) sought to define what an infrastructure is, only to conclude that an appropriate question is rather when than what. For Star and Ruhleder, while all infrastructures share common characteristics, they become infrastructures only in relation to a certain practices. Following Star and Ruhleder's path, Klein et al. (2012) suggested that micro-level practice theories constitute more appropriate level of analysis for infrastructures than macro- or meso-level theories. By focusing on practices many concerns related to the development infrastructures could be alleviated as 'practice theory does not artificially force information infrastructure [II] development into predetermined phases but views II development as the co-evolution over time of aligned practices' (Klein et al. 2012, p. 3). That is, such theories are potentially more ecological to the dynamical self-organizing nature of infrastructures that give raise to patterns of evolutionary development rather than reflect a prior determined design (Vespignani, 2009). Thus, we are 'thrown' as part of infrastructures that have not been designed per se but that have evolved to their present state; we have to work with and around that which the past has given to us. 'The prime example of a dynamical self-organizing system may be the Internet, but most communication infrastructures, road and transportation systems, supply networks, and power distribution grids are also dynamically growing networks' (Vespignani, 2009, p. 427). The historical development of infrastructures shapes also agency in important ways.

Hanseth and Monteiro (1997), found that the infrastructures embody its development standards that inscribe subsequent use behavior. That is, during the evolutionary development, the materiality of infrastructures reflects the principles according to which it was developed. Barad (2007) refers to this process of matter's becoming as sedimentation of practices. Matter is a process of becoming that sediments in itself the practices of its becoming, but also that the past (sedimented) practices shape the subsequent becoming or its enfolding (this is what Barad means by arguing that matter has an agentive role in its own becoming). To put it simply, the Internet still embodies the Internet Protocol (IP) standard (i.e., Request for Comments 791 (RFC 791)) from 1981 that shapes what can be achieved with it. What this implies is that agency is relational to the historical development of infrastructure. The relationship between material history of infrastructures and agency is further elaborated by Venters et al. (2014) in what they coined as trichordial view of agency. What the authors argued was that while any action takes place at present and is always oriented towards future, it is tightly anchored to the material history. The material history is especially salient for smart infrastructures as the 'smartness' is often built-upon existing material foundations rather than built afresh. These rigid, persisting, and messy layers of matter resist change and demand accommodation of actions that converge with its material basis (c.f. Pickering, 2008). Regardless of the qualitative differences that is likely to exist between the materialities of the 'real' world and those of the 'virtual' world, this same is certainly true, at least to some extent, for purely digital and information based infrastructures (e.g., IIs), as, for instance, the slow and painstaking transition to the next generation of IP (i.e., IPv6) has well demonstrated.

Polycentric and agentic constitution

Despite that infrastructures often depict an image of homogeneity and unity, any closer analysis reveals that in fact, they are amalgams of humans and non-humans, technologies and non-technological components, palpable and impalpable materials. As Bennett (2009) has argued, the power grid 'is a volatile mix of coal, sweat, electromagnetic fields, computer programs, electron streams, profit motives, heat, lifestyles, nuclear fuel, plastic, fantasies of mastery, static, legislation, water, economic theory, wire and wood – to name just some of the actants' (p. 25). What is particularly noteworthy in her view of power infrastructures, is that in lieu of viewing them as constituted by (passive) material objects (in addition to humans), its component parts are active actors, or actants in her Actor-Network-Theory informed terms (see Latour, 2005). But can material 'objects' have agency or is it too much of anthropomorphizing? As Knappett and Malafouris (2008) rhetorically puts it, '[m]aterial and nonhuman agency – surely this is a mistake?' (p. ix). The same kind of hesitation is also present in Bennett's (2009) theorizing that she herself calls quixotic. Indeed, authors such as Jones (1996) have criticized attempts to designate agency to non-human 'objects' and research projects that describe those objects with language and terms conventionally used for describing solely human traits. While these concerns should not be neglected, it is still beneficial to expand the purview of agency from the traditional human-centric designation (Rose et al. 2005) to a polycentric one.

For IS researchers, designating a form of agency to technology is likely cogent as we have gotten used to working with proactive technologies that seem to perform operations independently. Such technologies seem to perform actions in isolation, and independently from human intervention (once programmed to do so), such as indicated by automatic and scheduled batch jobs. Leonardi (2011) and Introna and Hayes (2013) note, the agency of technology seems capable of acting but lacks the intentionality in its mode of action that they consider as the distinctive trait of cognizant human agency. While such conceptions of agency are surely sufficient and relevant for certain studies (especially for those working at the human-computer interface), these conceptions omit important workings of agency that are particularly useful in infrastructure setting. Barad's (2007) particularly prominent conception moves away from describing agency as a designated property of any individual (whether human or non-human) into conception where agency is relational to the constitution of a particular phenomenon. That is, from this perspective, in infrastructures, agency is not a property of any single entity but polycentric in such a way that agency is the possibilities of changing ('reconfiguring') the constitution of the infrastructure. This requires some further elaboration.

As Latour (1984) has argued, we only achieve things by mobilizing other actors. His assessment resonates well with Bennett's (2010) claim that '[t]here was never a time when human agency was anything other than an interfolding network of humanity and nonhumanity; today this mingling has become harder to ignore (p. 31)'. As she continues '[w]hat is perhaps different today is that the higher degree of infrastructural and technological complexity has rendered this harder to deny.' (Bennett, 2005, p. 463) Even such prosaic task as conducting information search from a search engine mobilizes and leans on a host of forces whose operations are a little affected by human intention, but without which the search would not be possible; computers, electrons, photons, coppers, fibers, software, and algorithms to name a few of the actors involved. Especially algorithms that are often seen as merely instrumental and passive techniques of representation are anything but neutral and passive. Algorithms are active forces part of the infrastructural constitution that create and dynamically change the results of our search (Introna 2015; Orlikowkski & Scott, 2015). Further, the material linchpin the infrastructures form, have rendered the boundary between local and distant porous, as even that which is physically distant can have very palpable and concrete local effects. This is what Almklov et al. (2014) meant by arguing infrastructures reconfigure situatedness of (technicians') work. Thanks to infrastructures, we can (physically) locate in very distant places, yet feel proximity to one another (Wilson et al., 2009). However, none of this is to imply that infrastructures would render distances irrelevant in phenomenological sense. Rather, the infrastructures enact realities that are different than realities without those infrastructures (or with differently constituted infrastructures). And those realities foreground topological concerns that focus on boundaries and connectivity over geographical concerns of distances across space (and time) (Barad, 2007). Particularly for technicians working with smart infrastructures, topological concerns have gained priority over physical distances, as a central aspect of the 'smartness' is to enable remote control and diagnostics (Jonsson et al., 2009).

Dynamic and invisible agencies

One of the general tendencies of infrastructures, as asserted by several studies, is that they fade to background and become invisible in use (Star & Ruhleder, 1996; Pipek & Wulf, 2009; Graham & Thrift, 2007). Such assertion matches well with the everyday experiences with infrastructures – we only rarely notice the air-conditioning or the heating system in our offices, or the complex interconnections that form the network necessary for sending an email. Things change abruptly when the infrastructure fails to provide its services; the sudden sensation of heat when the air conditioning breaks down during summer's heat peak, or the unexpected and almost cryptic error message email client presents us when an email could not be delivered. However, even in such occasions of break downs, the infrastructure does not reveal itself in its whole complexity and glory. Quite contrary, what becomes visible is not the infrastructure per se but merely (part of) the service it provides. Despite that we are surrounded by these infrastructures and signs and symbols that indicate their presence, it takes conscious effort and expertise to make the infrastructure and its functioning visible[1]. Indeed, much of the formal business continuity and risk management work in organizations takes place around making visible the organizational infrastructure and its dependencies in order to surface potential points of break downs in that infrastructure (c.f. Suchman, 1995).

Jonsson et al. (2009) and Østerlie et al. (2012) have illustrated what technicians know about the smart infrastructure and its production processes rests on the materiality of technology, and on the materialities they jointly produce. Østerlie et al. (2012) refer to arrangement of humans, technologies, and sensors as 'dual materiality' to draw attention to the performativity of sensors. The sensors enable the technicians to know about the oil flows when drilling oil, but not in the sense that the sensors mediate some existing information to the technicians. The sensors do not merely extend the technicians capacities to go/see underground where the oil flows, as extension of eye sight to see things beneath the surface that the technicians are incapable of seeing due to the limits imposed by their corporeality. Instead, the sensors create new materialities for the technicians to work with (Østerlie et al., 2012; Jonsson et al. 2009). As such, incapability of not knowing about the oil flow without the sensors, is not about incapability of 'seeing' the flow. Rather, if these materialities do not exist in absence of the sociomaterial arrangement the sensors are a part of, then it is also incorrect to say that the sensors help us to 'see' by mediating a view from underground. Instead, the world and how we known about the world becomes inextricably intertwined. This intertwining of practices of knowing and the world is what Barad (2007) calls as apparatus. For her, apparatus is not any material arrangement or any sort of object, but it is a doing through which the world materializes. She refers to this doing as material-discursive practices. World is not composed of entities with predefined and clearly demarcated boundaries prior to our engagement with that world but becomes striated as we engage with the world (and how we engage with that world). In other words, the technologies (such as the sensors) do not merely help us to see hidden parts of the world (such as the oil flow) but they help enact those worlds. The way in which an infrastructure is visible to us is relational to the apparatus through which we know it. In smart infrastructures, the technicians work with materialities that reflect a prior decisions of what technologies and materalities are available and how the infrastructure is visible to them. The infrastructures are full of actors that (can) have an effect but knowing about those actors is limited to the sociomaterial arrangements of humans and technologies through which those actors materialize as actors and are 'made' visible.

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[1] Ingrid Burrington's guide 'Networks of New York: An Internet Infrastructure Field Guide' well illustrates the difficulty of seeing infrastructures and some of the expertise required to make them visible (See: http://seeingnetworks.in/nyc/ [2016-05-01])

Precarious and Discontinuous Material Foundations

While infrastructures (especially in the Western countries) often paint images of rigidity, stability, and permanence, their functioning ''is always a precarious achievement ready to untangle at a moment's notice through myriad of possible causes' (Graham, 2010, p. 11). Perrow (1981) has argued, complex systems, such as infrastructures, have a propensity for accidents. Thus accidents are not just exceptions for him, but 'normal' (i.e., an inherent) part of complex systems that cannot be removed from these systems. Butler and Gray (2006) have also argued the technologies such systems are composed of, are inherently unreliable and only achieve reliability thanks to human ingenuity in operating these technologies. Bennett's (2005) insightful and detailed study 'of the blackout that struck North America in August 2003' (p. 446), revealed how even these gigantic and enormously complex power infrastructures are inherently unreliable and unpredictable and become established through complex and uncertain processes that involve various actors. Infrastructures seem to form a unity of actors, but it is a unity that does not unify them. Rather, infrastructure is a whole in which the parts do not always share a mutual goal, and in which there is even occasional violence between the parts (c.f. Bennett, 2009). Such studies rework foundational assumptions of how we view the reliability and continuity of infrastructures. If we are to incorporate these insights to our theorizing, incidents and the like can no longer be seen as merely annoyances, or incidental moments of failure, but require a place in our theorizing. After all, infrastructures that are not available for use are of little use.

Building on her empirical analysis, Bennett (2004) recognizes the need to 'reserve a place in theory for the aleatory and in so doing display a kind of respect for the cunning thing-power of things.' (p. 359) By aleatory, she means that which is unexpected, surprising and erratic. Incorporating the aleatory questions the regulative ideal of agency 'as the accurate translation of ideas into effects' (Bennett 2005, p. 453) that 'chafes against everyday experience—where it seems that one can never quite get things done, where intentions are always bumping into (and only occasionally trumping) the trajectories of other beings, forces, or institutions.' (Bennett, 2005, p. 453). The moments when our actions bump with trajectories of other beings are the erratic moments when the infrastructure abruptly fails to perform to our expectations that gives raise to new pressing issues of finding out what went wrong and how to fix it (c.f. Pipek & Wulf, 2009). These are the moments when the expression of agency becomes most visible to us and questions our mastery, but also any human-centric conceptions of agency (Bennett, 2005; Barad, 2007). Barad (2007) refers to these expressions of agency as reconfigurations to describe the nature of these changes as shifting the material constitution of a specific sociomaterial arrangement. For her, the reconfigurations are neither deterministic nor fully predictable, but are always discontinuous (Barad, 2010). A breakdown of a sensor changes the material constitution of that infrastructure and the possibilities for further action (or reconfigurations) it affords.

Conceptualizing Infra-Acting

Building on the above discussion, infra-acting conceptualizes the relationship between (materiality of) infrastructures and action. Infra-acting posits that infrastructures shape action through four mechanisms. First, action is relational to the (material) history of the infrastructure that sediments practices of its becoming as a palimpsest of infrastructures. Second, actions are not performed in a vacuum or in isolation from the infrastructure's material fabric but takes place as part of that fabric; infrastructures are distributed yet tightly interconnected. The ways in which infrastructures entangle actors and their actions across space and time give raise to different conceptions local/non-local (and of proximity). Third, the agentic constitution of infrastructure is dynamic and evolving, but also visible only in relation to materialities through which we know that constitution (i.e., relational to an apparatus (Barad, 2007). Fourth, com-plexity and dynamic nature of infrastructures render the behavior of infrastructures inherently unreliable and unpredictable. That is, any action taken as part of an infrastructure is always on shaky (material) grounds. Figure 1 encapsulates infra-acting as a broad conceptual framework and is discussed briefly next.

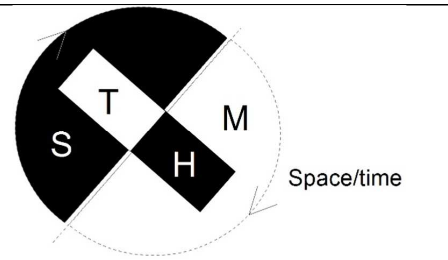

Figure 1. Conceptual framework of Infra-acting (T=Technology, H=Humans, S=Social, M=Material)

When situated as part of smart infrastructures, humans (H) and technologies (T) are always part of larger social (S) and material (M) context that constitutes the infrastructure. The infrastructure is never clearly demarcated, neither are its parts visible in any sort of totality or finality, but both the boundaries of infrastructure and its 'components' become enacted in practice (the dotted lines in Figure 1 represent the reconfiguring nature of infrastructures). Each action gives raise to different entanglements and boundaries of technology/material as the infrastructures' material constitution reconfigures. Thus, there is a reciprocal relation between action and the material constitution of the smart infrastructure. The infrastructures enact different conceptions of space and time such that 'near' and 'far' emerge differently in relation to the material configuration and constitution of the infrastructure. That is the smart infrastructures give raise to different forms and conceptions of space and time such that time and space are not fixed and given but become differently enacted, e.g., remote control and diagnostics systems reconfigure local/non-local boundaries (c.f. Almklov et al., 2014). Infra-acting provides a conceptual lens to make sense of the materiality of technicians' actions in a smart infrastructure context as will be illustrated. But before turning to empirical findings, methodological details will be outlined next.

Research Approach

The empirical material of the study is based on ethnographic research (Myers, 1999; van Maanen, 2011). Ethnography does not impose a prior restrictions or control on the study subject, but observes events and actors in their naturalistic environment and maintains constant openness of inquiry (Guba, 1981; Lincoln & Guba, 1985). To put it simply, '[w]e [ethnographers] talk with them [informants], we ask them questions, we listen to their stories and we watch what they do. In so far as we are deemed competent and capable, we join in.' (Ingold, 2014, p. 386).

As typical for ethnographic research, all observations were collected from a single site that was studied extensively (Hammersley & Atkinson, 2007). From October 2014 to May 2015 (2-3 days a week and 8 hours on average, except between mid-Dec to mid-Jan) I observed technicians at a centralized operations center that controls a smart power grid. While the technicians work 24/7, divided into two shifts (day shift is from 7 a.m to 7 p.m and night shift from 7 p.m to 7 a.m), I mostly stayed in the operations center and made observations during office hours. During the observations I asked the technicians to elaborate their work and explain what it was that they were doing. This was due to the fact that 'most work practices are so contextualized that people often cannot articulate how they do and what they do unless they are in the process of doing it' (Barley & Kunda, 2001, p. 81). Due to my lack of competence in power distribution, I had to develop an understanding of the related technologies and techniques and also of the local jargon. Despite the initial recalcitrance and suspicion (van Maanen, 2011), the technicians showed much interest in explaining and elaborating things that I did not initially comprehend. As I had unrestricted access to the operations center and to other parts of the building where the operations center locates, I was able to join also informal events such as coffee breaks, lunch breaks, staff meetings and trainings. In addition, I also collected purely observational material by following their work without any vocal interaction. I had plenty of opportunities for informal discussions with the technicians, but also with other employees, such as field technicians, and niche experts (the power grid is divided into different areas of responsibility and expertise, such that for instance some have specialized in relays, whereas others have expertise in power stations or in information systems). The operations center proved to be a fruitful space for interaction and observation as it seemed to function as a local 'market square' where employees would colligate to discuss their work related issues but also to discuss any personal topics as a form of recreational activity. In addition, I maintained openness for any emerging opportunities to collect empirical material that could shed light on the topic (Hammersley & Atkinson, 2007). I actively read publicly available material on the information systems the technicians used, studied power distribution techniques, followed news on power outages and legislative changes, visited a museum focusing on the historical development of power distribution, and so forth. I also was able to collect and study important (and even confidential) organizational documents, such as continuity plans, operations manuals, standard operations procedures (SOPs) and internal newsletters. While these materials did not directly contribute to the study topic, they were invaluable resources to begin understanding their world. Through this experience of living as part of the study context, or what Chughtai and Myers (2014) call as 'throwness' into the field, I gradually developed an understanding of their work, and got several comments from the technicians that I could start working as one of them. However, these were clearly complements and exaggerations, but I took them as signs that I had gained sufficient understanding of their world(s).

During the study I maintained field notes and stored any collected information for later analysis and reading. The content and style of the notes varied largely from one situation to another. As Jarzabkowski et al. (2014) note '[t]hey [field notes] are written under various conditions, which are not always conducive to note-taking, and may vary vastly based on focal interest, writing style, context within which they are written, and so forth' (p. 277). Often the field notes were taken by using just pen and paper as I felt this was the most convenient. The notes were elaborated later, often during the same day or the day after. Particularly, I made conscious efforts to also focus on the materiality of their work, by documenting what material object the technicians applied and how (Niemimaa, 2014). In addition, to later recall the environment and the technicians' workspace, I took photos to document material constitution of their work. However, while plenty of other material was collected, the field notes provided the primary source of empirical material. Later reading of the field notes relied on what Schultze (2000) refers to as 'head notes'. By head notes, she means the experience and knowledge gained through the extensive field experience without which the field notes lack meaning and context.

Van Maanen (2011) has shown that 'there is no sovereign method for establishing fieldwork truths. It is murky out there and in here.' (p. 138) Analyzing the empirical material was informed by qualitative data analysis techniques (Miles & Huberman, 1994) which involved noting down emerging ideas and categories inside and outside of the empirical site that would explain the relation between what the technicians did and material aspects of the infrastructure. The analysis followed an iterative analysis in which the theorizing progressed alongside with the field work and resulted from the interaction between empirical material and literature. In other words, these 'processes [of analyzing and theorizing] were not separate from the fieldwork as they continually fed back and impacted on the fieldwork' (Cecez-Kecmanovic et al., 2014, p. 571). Simultaneously with the field study, I actively read past literature. From this interplay between the field study and the literature (Klein & Myers, 1999) (especially on infrastructures and on sociomateriality) conceptual categories began to emerge gradually. The concept of infra-acting started to take shape during the empirically informed reading of the literature. The literature had discussed the implications of smart infrastructures to technicians' work but had not developed common theoretical foundations to which agential realism (Barad, 2003, 2007) emerged as promising framework to account for the materiality of infrastructure. Through iterations, the four conceptual attributes of infra-acting were formed. During these iterations, new emerging ideas and changes to old ideas were noted down. The categories were adjusted until I felt they could sufficiently capture the formal aspects of technicians' work and actions with the infrastructure.

Empirical site: SmartGrid Co.

SmartGrid Co. (a pseudonym) is one of 80 companies that are responsible for maintaining a power distribution network in Finland. While the power distribution networks are administratively divided into smaller parts, through a shared core network, they form an entangled whole. As the administrative responsibilities over power distribution are spread across many different companies in relatively small country, the companies are also relatively small. Often the administrative boundaries of the power grids have evolved around a city or a municipality that is a legacy from the past intercity power systems. The grids are connected via a core grid that is operated by single company called Fingrid Co. The companies are much regulated by the society as within a certain area only a single company distributes the electricity which would allow the companies to operate in situation that is not far from a regional monopoly. As such, the companies are required to distribute electricity that a customer might have bought from another company and charge only a fee that is set by a regulatory body. As such, the companies mainly compete by selling electricity rather than distributing it. In addition, during recent years, several storms have swept over Finland leaving thousands without electricity for days. The power outages have been a stark reminder for the society of its dependence on electricity and have made the legislators to react. As a result, in 2013, a new regulation was enacted that requires the companies to increase the reliability of their power distribution. Meeting the regulatory demands have mainly resulted in slow and expensive investments to increase the proportion of ground cables in contrast to air wires, and to increase the automation and 'smartness' of the grid. Thus, the companies operate their distribution network under strict legislative framework and under increasing societal demands for constant and uninterrupted flows of electricity.

The SmartGrid employs around 300 persons, operates a power grid in one the largest cities in Finland, and is thus also one of the largest power distributors in Finland (when counted by the number of customer subscriptions). However, due to legislative reasons, the power grid operations are the responsibility of a subsidiary, where a small core group of around 20 technicians (plus a number of field technicians) handle the daily operations and planning. It is also one of the country's oldest power distribution companies – its roots date back to the beginning of 1900. The long history is much present still today, as the company operates physically in the same location where it was founded. New office buildings have been built around the old power station which still includes some old steam turbines that are nowadays merely props used to showcase the company's long history and the development of electricity production.

During this long history the technicians' work has also significantly changed. Technological development has meant that technicians who had to be locally present in each substation, could be moved from the distributed substations to a centralized operations center. This change has also increased the company's reliance on IT technology, as, still today, if the connectivity to the sub-stations would be lost, technicians have to populate each and every substation until connectivity is restored. Thus, the IT technology and the power grid have tightly commingled. Since 1999 the substations' operations have been operated from a specialized information system, known as supervisory control and data acquisition (SCADA) system. More recently, various IT technologies have been introduced that have increased the entanglement of the electrical and the 'electronic'. Power grid automation that can automatically react to power outages, and remote diagnostics and control systems communicate using Internet Protocol (IP) and embody embedded Linux operating systems. Any demarcation between the power grid and the IT technologies has thus been rendered beyond recognition. The technicians work environment at the operations center is filled with technologies. There is no single overarching 'work system' that the technicians use to perform their work tasks, but instead, a number of information systems and other technologies scaffold the work (Orlikowski, 2006); IP phones, dedicated phone system for society's critical functions, SCADA, coordination and geographic information system. The technicians' boomerang shaped long desks are filled with rows of large displays, and in front of the operations center is a large display couple of meters in diameter. In short, the operations center is much like any other contemporary operations center. The contents of the large screen vary in relation to work tasks, but most often it displays the overall status and topological configuration of the network in a simple wire frame diagram on a graphically simple Unix operating system. Thus even the graphics remind that this is an industrial setting where things are built for functionality, and not as flashy and trendy white design items. Despite that the power grid is formed by complex amalgam of nodes, switches, relays and so forth that are connected by various media, such as fiber optics, copper and radio signals, that vary in their age and functionality, their representation on the SCADA gives an image of a homogenous setup where different colors seem to differentiate the components of the grid.

Infra-acting with Smart Infrastructure

Technicians working in the operations center coordinated maintenance and repair work from a centralized location that at first would seem highly local and technology intensive expert work. However, observations of their practices formed a more complex image of the work where histories matter, where multifaceted and dynamic agencies converge and collide, and where non-local effects and local actions entangle. When situated as part of infrastructures, technicians and their actions become part of a distributed but coherent whole in which the parts form a whole but a whole that is not harmonious and predictable. Next, illustrative examples of the relationship between technicians' work and materiality will be given.

Knowing the history and the historical materials of the infrastructure

The power grid has gradually and over decades evolved to its current state that reflect the practices of its development and design. Reflecting this history, the power grid is not a homogenous set of components but an amalgam of components that range from electrical and electronic to mechanical that are all tied together as a network through various types of copper lines, fiber optics and wireless signals. The form and structure of the network, its topological configuration and content, embody design decisions, standards, socio-politics, economics rationality, workarounds, technological development and so on that all contribute to its materiality shaping and even inscribing behavior (Hanseth & Monteiro, 1997).

The power grid, despite the gradual reworking, still reflects the practices taken decades ago. As one of the informants explained, design of the power wires and cables that was made decades ago often followed the shortest path which resulted in pathways going through forests, rather than, for instance, on the side of a road where they would be more protected from falling trees and branches. In addition, air wires have traditionally been economically more feasible way to implement the network than cables that go underground. Thus the economic rationale guided much of the implementation which the power grid even still today reflects. While during past years the company, as most other power distributors in Finland, have been encouraged by legislators to increase the weather resilience of the network by changing the air wires to ground cables, the task is slow and expensive. As Hanseth and Lyytinen (2010) state, infrastructures, when implemented, are not built afresh but are reworked iteratively. The sedimentation creates inertia for change, but not as strict path dependency. The historical decision and practices of the power grid limit and enable the technicians' enactment of their agentic capacities in order to realize certain goals. Yet it is the persistence and sustainability of the power grid's materiality that gives raise to the very existence of the infrastructure and enable its continuity (c.f. Brown & Duguid, 1994) but that would decay without active maintenance and repair (Graham & Thrift, 2007).

One of the daily routine practices the technicians engage in is rerouting of the electricity for maintenance work. The power grid equipment require periodic care that can range from renewing (too) old components, cleaning the equipment, and testing the failsafe mechanisms and the related alerting system. All of the maintenance actions are coordinated from the operations center and require collaboration between technicians at the operations center, the field engineers, and technologies. Whether a certain operation can be performed is determined in relation to several factors dependent on the materiality of the grid. Each maintenance work is documented as a standard operating procedure (SOP) that function as informational source (Suchman, 2007) during the maintenance work. Each SOP is always verified and simulated by another technician be-fore the actual change takes place. The main purpose of the SOP is to ensure safe and reliable operations in a hostile environment where mistakes can have severe consequences, and result in severe injuries or even death. But what they also indicate is that the procedures are much governed by the material structure of the infrastructure and the possibilities it affords. Each steps in the SOP contains short instructions what action needs to be taken and are documented in the or-der they should be performed (in some occasions, the SOPs have to be adjusted in situ which should be, as a principle, always avoided). Thus, the SOPs reflect decisions on what, and even whether and when, the actions can be taken. Indeed, in some occasions, certain actions cannot be enacted due to hazardous conditions it would result or because the actions would reduce the resilience of the network to withstand unpredictable incidents. For instance, on some occasions the procedure would document step to coordinate the field engineers to manually turn a mechanical switch that could also be turned remotely without the need to physically visit the location. However, the physical turning of the switch is seen as a more safe action to turn a cable 'cold'[2] when working with the cable attached to a specific switch. Further, by physically visiting the lo-cation the field engineers are able to place a neon

[2] Technicians use profession-specific jargon intensively when describing their actions (Orr, 1996; Barley, 1996). For instance, 'cold' refers to a cable or a device that had been disconnected from electricity.

sign 'men at work' on the switch to prevent other engineers to connect electricity on the cable should there be some coordination error or similar condition. On the other occasions, the remote control capabilities may enable action that would have been difficult or unsafe due to the historical development of the grid. Certain locations contain switches that are decades old. While they still function, operating these switches locally can be hazardous. As the informants explained the 'electricity may jump at you if the blades don't open quickly enough'. The technicians coordinating the work had learned either through experience or vicariously which parts of the network contain such components (also the SOPs reflect this). To operate such switches, the technicians would use remote control to control another switch upstream on the path which the electricity flows in order to disconnect the flow of electricity from the switch that would then open possibilities for safe operations of the switch that had been deemed less safe. As such, the technicians and the information systems affording remote control rework possibilities of material history of the grid that defies any strict deterministic path dependency. The actions the technicians take and the material history of the grid are tightly entangled which gives rise to different and differing possibilities for action that is agency. Thus, each change would have to be evaluated against and is therefore relational to the current material configuration of the power grid. In a similar manner, each action and change reconfigures the possibilities for further action and change. As Barad (2007) argues, matter is an agency in its own becoming; matter is a process of congealing that enfolds rather than unfolds.

Harmonizing distributed but connected actors

The power grid forms a distributed network type of structure that is dependent on various agencies of which none can fully determine its functioning. Yet it is a whole in which all agencies have possibilities to make a difference and have an effect. Performing any action necessitates convergence and coordination of actors that involves not only humans, but also non-humans, palpable and impalpable, cultural/artificial and natural agencies that all play a part in how specific action materializes and what effects the technicians are able to produce as part of the amalgam.

When maintaining the continuity of power grid the technicians attempt to mobilize and coordinate various agencies which enhance and reduce their possibilities to enact specific actions. While much of the work seems to unfold in the nexus of different IT systems' local interfaces, the actions the technicians perform are often relational to other more distant agencies. Their actions do not merely build on the local interface but are founded on the distributed materiality of the smart power grid. Such is the case, for instance, when the technicians repair the grid. Detecting errors in the grid and the fault locations would not be possible without the IT technologies and sensors (e.g., electricity in a cable is not visible per se), and actions in response to outages in the grid would take place in the scale of seconds (or even minutes) in contrast to reaction times of the technologies that enact response in milliseconds. The entanglement of work and technologies gives raise to realities that transform matters of distance less relevant than matters of connectivity. However, in addition to these technologies, customers often play a part in producing materialities for the technicians to work with. Often, they provide images or descriptions of events they have witnessed. For instance, promptly after an incident was registered by the control information system, a customer called to the operations center in order to provide details of the exact location and his visual on a 'large flash of light coming from a box connected to a pole'. The technologies, customers and technicians entanglement engender materialities that the technicians use to construct likely explanations. As in this specific case, the technician surmised that 'it is likely a critter that got itself electrocuted', and was later confirmed by one of the field technician's sarcastic comment that 'a squirrel is taking a nap on top of the converter'. Through the entanglement of humans and the technologies, technicians' possibilities for action are collaboratively constructed in relational to the constituent agencies and available materialities. As this incident indicates, the agentic constitution of power grid is highly distributed, yet it is also highly connected.

The infrastructure forms material ties as forms of connectivity between the actors that only gain their significance to technicians' work in relation to an enactment of practice. These actors colligate through the relations formed by the material ties to form a whole; actors emerge as meaningful, effects become significant and changes felt. Sensors, remote diagnostics and control technologies form types of connectivity not present in different technological constitutions. These technologies when implicated in technicians work enact different realities in which local is not merely that which is in the reach of an arm, but that which is connected.

Making the constitution of material fabric visible

While the infrastructures structure technicians work, the technicians also infrastructure their work (Aanestad et al., 2014). This involves what Orlikowski (2006) calls scaffolding – the technicians dynamically shift and transform the technological and material constitution of their work. What the power grid, as an infrastructure is, is ontologically a dynamically changing/shifting multiplicity rather than a single entity. That is, the boundaries of an infrastructure are not clearly demarcated but are porous. Different materialities matter without which the work would unfold differently; scrapbooks, yellow paper notes, various web services, closed circuit televisions (CCTVs), mobile phones, manual logbooks, printed operating procedures and so forth dynamically become part of and form the infrastructure (Orlikowski & Scott, 2008) without which the technicians field of action would be narrower. Also technologies afford certain possibilities for action only in when combined with other materialities. Thus, infrastructures always contain a degree of openness (c.f. Hanseth and Lyytinen (2010)) through which its constitution is always open to redefinitions, for inclusions and exclusions of actors that matter.

When coordinating and performing routine maintenance, the technicians followed SOPs that were created and stored on a power grid management software. The software ensured each step would be performed in the order in which it was planned, and after each successfully performed step, the step would be marked as completed in order to move to the next step. However, the technicians also printed out the plan and had both, the electronic and the paper list in front of them. While they would perform the steps in the software, they also marked 'OK' on the printed SOP, but also wrote other relevant notes. For instance, when rerouting the electricity, the technicians would mark down numerical values taken from another information system, from the SCADA, at the reach of their arm. These numerical values would indicate whether the capacity of the equipment would be enough to afford the configuration change. Incorrect actions would launch the protective mechanisms that the grid embodies and likely cause outages, or even equipment damage. Their coordinating actions thus reflected the joint performance of technological and non-technological material that entangle in the technicians work.

The technicians rely mostly on voice communications when coordinating the field technicians' work. A separate mobile network, provided by the Finnish contingencies agency, provides the main communication channel for the purpose. The mobile network is isolated from the normal public mobile network to ensure the network does not get congested and clogged in emergency situations and the network has a longer battery backup to withstand prolonged and large-scale power outages. The network is only available to organizations responsible for the most critical functions of the society (e.g., power distributors, emergency services, police, and fire services). While it has multiple communications channels and each has their specific defined uses, the communication follows a protocol in which each communication begins by stating who is being reached and by whom to which the receiver replies (e.g., 'operations center listening'). The communications, in case of routine maintenance, follows the procedure documented on the SOP in such a way that the technician at the operations center first gives instruction which is then repeated by the field technician before the actual work takes place. While the communication technology builds on generic mobile network (and the communication device resembles a mobile phone), the communications is kept very brief and clear. However, as the technicians communicate and coordinate, often a need to discuss specific details related to the task at hand emerges. On these moments, a need to expand the field of action emerges as the communications protocol of the dedicated communication channel does not afford lengthier discussions. Instead, the technicians establish another communications channel through public phone/mobile network to discuss the details. This action expands the technicians possibilities to act, and materializes the sociomaterial communication protocol in their action (i.e., the field of action is neither solely related to the technology nor to the 'social', but to their entanglement in action).

Working with vagaries

Enacting the agentic capacities seems to always embody a degree of uncertainty and unpredictability in a way in which the technicians intended action and the outcome of that action do not always meet. Unpredictability that is relational to the complexity of the environment is constantly present even in the most routine and everyday activities. That is, the actions always contain a degree of uncertainty and aleatory when working with materialities that are unpredictable, unreliable and imperfect.

An almost palpable feeling of uncertainty constantly prevails in the technicians' work. The technicians seem to accept that the functioning of the power grid is not fully in their control, but is always unpredictable. Heavy winds often tend to cause outages by falling trees or breaking tree branches on the air wires or by flying small objects (such as empty plastic bags) on the wires. As such, constant wind and weather forecasts bought as a service from meteorological institute form a visible part of the large screens at the front of the operations center. If the wind forecast indicates heavy wind, the company increases its level of incident preparations by, for instance, dispatching more technicians to on-call duty. The technicians collect information from multiple additional sources in order to predict and prepare for possible upcoming outages. They communicate with field technicians who are often working outside (or are on the road) and can sense the weather and any changes in it. Also a public fault notification service of their neighboring power distributor provides often valuable information on making predictions of upcoming outages. The technicians indicated that, based on their experience, when the service shows outages in the neighboring power grid due to heavy winds, they are also likely to have outages soon as well. The sense of increased predictability increases sense of control. As such, the technicians dynamically entangle with various other infrastructures that infrastructure their possibilities for action by shaping what they know and how they know it. Nevertheless, a constant uncertainty remains on where and when exactly the outages will appear that seems to create anxiety among the technicians, even to such extent that some have changed company or position due to the inability to withstand the related anxiety and the sense of lack of control. Wind is indeed unpredictable colleague. Despite the unpredictability of the winds, the winds are one of the most predictable threats. More difficult are pesky critters and birds that climb or fly in to different components and come in contact with the air wires, careless excavator drivers that cut cables when digging the ground plus a number of other causes that are unforeseeable before the moment of their occurrence. While all these agencies become dynamically, abruptly, and unpredictably entangled with the infrastructure and shape the technicians actions, the aleatoric and discontinuous nature of the grid is also present when the technicians perform actions.

The remote control buttons on the graphical user interface hide behind the simple graphical representation a complex mesh of actors that shape the technicians action that neither always perform as predicted nor are determined by technicians' intentionality. Enacting the simple action mobilizes a complex amalgam of actors that are electronical, electrical and mechanical agencies; the movement of the hand and the mouse cursor, the processing of the command in the information system, the remote command and control signal, the electrons and the light waves that carry the command, the signal receiver, the mechanical motor that operates a switch, and so forth, as well as the more unforeseeable actors that occasionally partake in the action (e.g., the winds, the critters, the excavators). It is truly a coordinated action that is dependent on the harmonious and joint performance of all the agencies. Often, however, the harmony and the collaboration of agencies seems as a distant fantasy, and instead friction and violence between the parts prevail. The agencies often become effective, meaningful and visible only when they break up the harmony of the grid, which is also most often abruptly. Infrastructures seem to become visible only upon break downs (Star & Ruhleder, 1996), but not in their entirety but only in piecemeal. While in some cases the technicians are able to construct a posterior explanations for why a certain action could not be performed, on other occasions the complexity and unpredictability seem to exceed their ability to construct plausible explanations (c.f. Orr (1996)). Broadly, however, in both cases, enactment of the action produces outcomes that differ from the intended due to often non-local causes that have local effects. On one occasion, the technicians performed routine operation to change the configuration of the grid, but as one of the technicians enacted a specific command, the grid did not respond to the command and the action did not impose any noticeable and expected change. As the command failed to execute, the technicians engaged in fault diagnostics to construct explanations for the outcome (or lack of it) that was then verified by a field technician. The specific component of the power grid was connected through a wireless link, but in a distant place which meant the signal had to be amplified by another device in between the operations center and the erroneous component. However, the physical place where the signal amplifier located had been without electricity already for few hours due to an unrelated other incident and consumed its battery backup. The signal without amplification could not carry all the way to its final destination and execute the command. On another occasion, where a command execution failed the technicians could not construct explanation and accepted that the power grid, occasionally, works in mysterious ways. However, of importance here is not whether the technicians are able to construct a posterior explanations, but that the actions always embody a degree of uncertainty when working with infrastructures.

Discussion and Conclusions

In this paper, I have studied the ways in which context gives raise to and shapes practices by focusing on the relationship between materiality and technicians' actions in a smart infrastructure setting. As such, this paper can be seen as a response to calls to study the 'new frontiers' of work (Forman et al., 2014) and to calls provide sociomaterial ethnographies on the active role of matter (Cecez-Kecmanovic, 2014) in a smart infrastructure context (Constantinides et al., 2016). From the interplay between the field work, the empirical material, literature on sociomateriality and agency (Barad, 2003, 2007; Bennett, 2005), and on infrastructures, I uncovered four mechanisms of *infra-acting* that shape the manifestation of actions and practices. I summarize the infra-acting mechanisms, their corollary manifestation of practices in the technicians work in Table 1 together with the more specific implications for research. Next I will provide some reflections on the broader implications of this research.

The primary contribution of this research is the concept of infra-acting that has implications to understanding infrastructures as a context for work and IS use, and to sociomaterial agency. Past studies have provided empirical insights into technicians' work in smart infrastructure contexts and shown the ways in which these infrastructures open new possibilities for work (Jonsson et al., 2009; Almklov et al., 2014; Østerlie et al., 2012). This research has sought to extend these studies by focusing on the ways in which these infrastructures constrain and enable action. Infra-acting draws attention to infrastructures as a material context for action and to the entanglements the infrastructures create. It extends discussions on sociomateriality and agency beyond the recognition that human agency and materiality are entangled (e.g., Leonardi, 2013; Orlikowski & Scott, 2008) by uncovering mechanisms of how the entanglement shapes practices. Further, IS research has recently conceptually developed the notion of distributed and relational view of agency (Mahama et al., 2016), but has lacked empirical applications.

Infra-acting posits that when action is situated as part of infrastructures, the action rarely lies with individual humans or solely in technology and is instead attributed to a complex amalgam of human and non-human actors that need to be considered as heterogeneous, distributed, unpredictable, and agential configurations. While it might be true that we never achieve anything without mobilizing other actors (e.g., Latour 1984; Bennett, 2009), infrastructures seem to render this aspect more salient and visible (Bennett, 2005). The technicians seem not to locate at the center of action but as part of the possibilities of the entangled whole (Barad, 2007). The trajectories of the technicians' work become entangled with trajectories and actions of other human and non-human agencies, regardless of whether they are 'local' or 'non-local' (Almklov et al., 2014). These entanglements importantly shaped the ways in which the technicians' practices unfold and the technicians' performance of work to meet the increasing demands for reliable and continuous flows of electricity at SmartGrid. Thus, rather than viewing the reliability to emerge from their cognitive abilities (c.f. Butler & Gray, 2006), the reliability becomes performed in this entangled whole that constitutes the infrastructure. On a more practical level, when recognizing that in the performance of such technology-enabled work the technicians and technologies are inseparable, also analysis should focus on the entanglements rather than on individual actors (whether humans, or non-humans like technologies). Infra-acting contributes to our understanding by showing that for instance, the material history is entangled with the technicians' performance and thus cannot be separated when analyzing the reliability of their performance. At SmartGrid, this was apparent, for instance, in the ways the technicians sought to work with the challenges created by the material history and its friction for change as the exposed air-cables worked counter to the evolving organizational and societal demands of higher degrees of reliability.

Infra-acting mechanisms		*Corollary manifestations of actions in technicians' work*
Historicity and sedimentation of practices. While any action takes place at present and is oriented towards future, it is tightly anchored in sedimented history of practices that enable the continuity of infrastructures but also limits possibilities for action.	⇔	*Knowing about and with local materials.* Local idiographic expertise is embedded in and enabled by the material history and the traces of that history the matter carries. That is, expert knowing is not primarily about knowing of infrastructures, but knowing about *the* infrastructure (expert knowledge is different from

		professional knowledge that is often generic, abstract, and technical). However, what is known is relational to how they know it (with what materials)
Implications: Confirms the role of history for agency and action (Venters et al., 2014; Cousins & Robey, 2005), but extends the discussion with a view of infrastructure history as palimpsest that carries traces of the practices of its becoming rather than a structure enacted in practice.		
Polycentric and agentic constitution. Action is not indexical to human actor. In infrastructure settings, agency is not an individual property but relational to material constitution of that infrastructure. Effects do not follow a cause but are relational to a cascade (Bennett, 2009).	⇔	*Harmonizing of agencies as a form of coordinating.* Technicians' action is not to have oneself perform but to have others do so. These include not only their human compatriots (field technicians and customers), but technologies and other non-human actors. Technicians' actions seek to harmonize the sheaf of agencies to achieve veneers of permanence and stability. Infrastructures unify and connects actors but does not unify which gives raise to practices of harmonizing When the active force of others is recognized, it becomes insensible to discuss about coordination but to discuss about harmonizing the agencies.
Implications: Confirms the insufficiency of anthropocentric and 'technocentric' agency (Rose et al., 2005; Mahama et al., 2016) when dealing with (smart) infrastructures. Extends the conceptual discussions with an empirical study showing that agency inheres in the relationship, not in actor (Knappis & Malafouris, 2008; Bennett, 2005; Barad, 2007). Contributes to the discussions on the role of individuals and their cognitive capacities to infrastructure continuity and reliability (Butler & Gray, 2006) by suggesting that what is needed might be to focus on discerning and tracing networks of actors affecting erratic situations and incidents rather than focusing on designating response and blame on individuals.		
Dynamic and invisible agencies. Agency in infrastructures is not fixed and diachronic but dynamic. Agency is not just about episodic and cumulative encounters with technology but a constant flow and flux of reconfiguring possibilities.	⇔	*Diagnosing as making infrastructures visible.* Infrastructure does not reveal itself to technicians in its totality but is visible only in relation to practices and materialities through which it is known. The technicians do not know in practice the agentic constitution of the infrastructure and those they have to work with. Instead, actors become visible and meaningful (occasionally abruptly) in ways that is afforded by the materialities at hand that shape what they know about and can do with the infrastructure (e.g., disruptions related to excavators or fallen trees engender different repair actions but only to the extent the materialities at hand afford distinguishing between the two).
Implications: Extends discussions that have asserted infrastructures are invisible and visible on break downs (Star & Ruhleder, 1996; Pipek & Wulf, 2009) by suggesting that infrastructures emerge only partially visible on break downs and need to be made visible; infrastructures emerge visible only in relation to enacted practices and materialities in use, but never in their 'totality'. Contributes to research on the materiality of technicians work (Jonsson et al., 2009) and extends the research by showing that the technicians knowledge of infrastructure is shaped by 'dual material' arrangements (i.e., the sensors)(Østerlie et al., 2012) but also by the broader material and agential		

constitution of the infrastructure (e.g, the customers, the field engineers).		
Precarious and Discontinuous Material Foundations. When working with infrastructures, it is impossible to know for sure the outcome of an action before the enactment of that action.	⇔	*Vagaries of actions as failures to perform reliably.* Working with infrastructures embodies a degree of uncertainty. As complex and open reconfiguring amalgams, their behavior is never predictable in practice. Failures of the infrastructure to translate intended actions to actions engender unreliable work performance.
Implications: Contributes to research by suggesting agency in infrastructures cannot be merely about accurate translation of intentions into effects, but needs to also account for erratic translations as expressions of agency. Extends research on IS use (e.g., Straub, 2012) by suggesting that the unpredictable and the erratic should be central for theories on use. Extends discussion on how work influences infrastructure reliability (Butler & Gray, 2006) by illustrating that the work not only influences the reliability of infrastructures but that the infrastructure shapes possibilities for reliable performance of work.		

Table 1. Summary of entanglement of materiality and action.

While I have shown in this paper how the technicians' practices emerge from and are shaped by the materiality of the smart infrastructure, I have not touched on the topic of how the findings should shape our design and implementation methods and practices. However, knowing the underlying mechanisms that shape the work around infrastructures may provide fruitful foundations when designing new information systems that become situated and used as part of the evolutionary trajectory of any particular infrastructure. As such, while the use of any IS is likely to always be, at least partly, emergent, future research should analyze whether any design and/or implementation principles for smart infrastructure systems can be derived from the mechanisms that create the space for infra-acting. Further, as I have focused on a specific empirical setting and a specific type of smart infrastructure (smart power grid). Thus, future studies should apply the concept of infra-acting to other infrastructure contexts to increase understanding on the generality of the concept and whether the same mechanisms emerge as salient to explain the patterns of actions. Such studies could also take use of quantitative approaches which would require scale development but might, as a result, yield understanding on the generalizability of the findings.

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– I, too, have forgotten my umbrella. –

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