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.

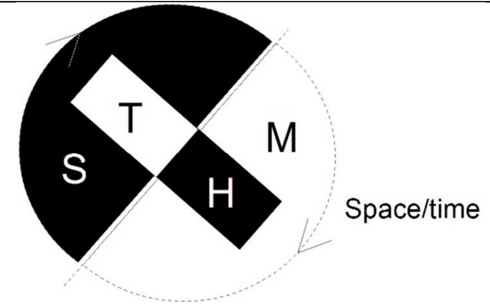

Figure 1. Conceptual framework of Infra-acting (T=Technology, H=Humans, S=Social, M=Material)

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

<table>
<tr><td></td><td></td><td>professional knowledge that is often generic, abstract, and technical). However, what is known is relational to how they know it (with what materials)</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>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).</td><td>⇔</td><td>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.</td></tr>
<tr><td colspan="3">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.</td></tr>
<tr><td>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.</td><td>⇔</td><td>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).</td></tr>
<tr><td colspan="3">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</td></tr>
</table>

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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