Final version available at Springer : http://dx.doi.org/10.1007/s10606-017-9302-0

Infrastructuring as Ambiguous Repair: A Case Study of a Surveillance Infrastructure Project

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Abstract

Health and welfare organisations are under increased scrutiny regarding their ability to make innovations in and increase the productivity of their services by digitising and automating them. Our empirical case study focuses on the implementation of a new health and welfare surveillance infrastructure project in a large Norwegian municipality. The infrastructure project led to significant challenges for various reasons, such as coordinating with vendors and subvendors, balancing governmentally defined purchase and implementation processes with local work practices, tailoring packaged solutions, and the differing concerns of many actors across different municipal departments. The case study investigates how the infrastructure project moves through ongoing cycles of breakdown and repair in order to implement a working infrastructure. Key to our analysis is the way repair plays out as the infrastructure project deals with the ambiguity resulting from uncertainties in relation to both how technology works in practice and how the project will be organised. We empirically analyse three collaborative repair mechanisms: value-network repair, process repair, and participation repair. Our study enriches the understanding of infrastructuring by discussing the collaborative repair mechanisms necessary for mobilising and adapting the practices, systems, and processes that coexist in infrastructure projects. Additionally, the concept of ambiguous repair suggests that tensions cannot be permanently resolved but rather should be considered an ongoing and necessary part of practical infrastructuring.

Keywords: Infrastructuring, information infrastructures, large projects, ambiguity, repair, empirical, case study, health and care

1 Introduction

In this paper, we analyse the collaborative implementation of a new patient surveillance infrastructure for 36 residential homes in a large Norwegian municipality. It is a representative case in healthcare, where technology and automation are expected to sustain safe, cost-effective, and patient-friendly health and care services in the face of mounting pressures, such as increased costs, the ageing society, and chronic illness (Ellingsen et al. 2013; Williams 2016).

Using digitalisation to change healthcare practice is notoriously tricky. Over the last 20 years, traditional digitalisation projects in the health sector have largely *remained* projects, leading to the problem of 'pilotism', that is, a failure to realise permanent changes in healthcare routines. Consequently, policy makers are now calling for large-scale implementation of digital solutions in routine health service delivery (Andreassen et al. 2015). Such large-scale digitalisation processes have specific challenges, such as the multiplicity of current and future users, the presence of many different systems connecting to or extending the infrastructure, and achieving a balance between standardisation and differentiation (Monteiro et al. 2013; Williams 2016).

As we move from pilots to large-scale implementations in healthcare, projects become significant agents of change, connecting a comprehensive network of digital systems and modules, practices, and actors (e.g., various user groups, managers, and vendors). This paper explores such a large-scale implementation project (henceforth referred to as 'infrastructure project') from the perspective of information infrastructures (Star and Ruhleder 1996; Bossen and Markussen 2010; Parmiggiani et al. 2015). Information infrastructures are characterised by an openness to the number and types of users, the evolution of interconnections among numerous systems, and new systems that shape and are shaped by existing systems and practices (Monteiro et al. 2013). Our health and welfare surveillance project had to address different user practices (36 health and welfare centres), different existing technical infrastructures (e.g., new and old buildings, existing alarm systems, information technology maintenance contracts), governmentally defined public procurement regulations, different vendors (contractors and subcontractors), and new and packaged IT solutions. The project also had to address uncertainty on two levels. First, there was sociotechnical uncertainty regarding how the new infrastructure would work in practice (i.e., new ways of working and collaborating). Second, there were uncertainties with regard to how the large infrastructure project should be organised to encourage the municipality (with several management layers and different departments such as healthcare, IT, and building construction) and vendors (with subcontractors) collaborate to achieve the project goals. The infrastructure project can therefore be described as ambiguous, because the outcome (the resulting infrastructure) was not known; moreover, the procedures determining the outcome (i.e., how to make different systems and practices collaborate to achieve the outcome) were also unclear. Ambiguity has consequences for project work, because it obstructs easy interpretation and planning, requires integration of disconnected discourses, and requires people to participate in shared meaning making (Gaver et al. 2003).

We therefore ask the following research question: How does an infrastructure project move forward productively in the midst of ambiguity? In investigating this question, we draw on recent studies of infrastructuring and repair that have highlighted the ongoing, provisional, and contingent work that enables infrastructures to work (Parmiggiani et al. 2015, p. 424). These perspectives extend Star and Ruhleder´s (1996) argument that infrastructure has an invisible quality until it breaks. Although invisibility may certainly be one aspect of infrastructure, 'it is only one and at the extreme edge of a range of visibilities that move from unseen to grand spectacles and everything in between' (Larkin 2013, p. 336). Rather than considering infrastructure projects strictly according to the invisible/visible or broken/fixed dichotomy, we seek to capture the ongoing and contingent activities of *repair* that go into making an infrastructure project work (Jackson 2014). We specifically target the collaborative repair work required to deal with ambiguity in infrastructure projects. Central to our argument is that these forms of collaboration are not easily defined a priori, but contingent on humble and ongoing cycles of breakdown and repair in infrastructuring practice. We discuss three repair mechanisms that, according to our analysis, are relevant to infrastructuring:

- *Value-network repair*, which is how the project worked towards establishing forms of institutional and inter-organisational collaboration and discourses that could effectively monitor the infrastructure project, make decisions, and continuously adjust the project´s path.
- *Process repair*, which is how the project achieved a balance between governmentally defined purchase and implementation regulations, on one hand, and the need to achieve local meaning for each health and welfare centre in order to engage, learn, and adjust, on the other.
- *Participation repair*, which is how the project used material artefacts to encourage the active participation of users in the shaping and adaptation of packaged solutions.

The paper is organised as follows. Section 2 explains the relevance of the infrastructure literature to an analysis of tensions in large-scale health and welfare projects as well as the relevance of articulation work, infrastructuring, and repair to this analysis. Section 3 introduces the background for the surveillance infrastructure, how we came to study it, and how we identified the mechanisms (value-network repair, process repair, and participation repair) by analysing the infrastructure project´s episodes of breakdown and repair in light of the infrastructuring and repair literature. Section 4 empirically illustrates these mechanisms. Section 5 provides a discussion of the findings in light of both the literature on infrastructuring and that on repair. Section 6 sums up our argument and outlines some implications of considering infrastructuring as ambiguous repair.

2 Background

2.1 Infrastructures in health and welfare

Insightful workplace studies have developed powerful concepts such as situated action, flexible workflows, situated awareness, articulation work, invisible work, material resources for action, and common information spaces (Blomberg and Karasti 2013). These contributions have foregrounded problems with both formalised representations of organisational processes (Schmidt 2009) and standardised and packaged/universal solutions (Monteiro et al. 2013). These insights highlight the necessity of context-specific solutions, leading to suggestions that systems must be built according to the uniqueness of particular organisation forms.

However, brick-and-mortar organisations, where health and care represent a case par excellence (Fitzpatrick and Ellingsen 2013), continue to implement large-scale and packaged software applications and systems (Wulf et al. 2015). There are reasonable rationales for this. First, aligned with top-down management interests (Ciborra 2000), the implementation of standardised solutions is considered a strategic means of coordination, organisation, and collaboration across different contexts (Rolland and Monteiro 2002). Standardised solutions enable coordination, which in turn enables levels of control across distance (Law 1986). Second, large-scale systems are seen as part of the solution for challenges confronting the healthcare sector, such as integrating services, improving quality and efficiency, serving an ageing population, and chronic disease (Williams 2016).

There is an inherent tension between the need to facilitate local and short-term practices and the need to establish large-scale integrative information systems that enable standardised, efficient, and manageable sociotechnical practices. The information infrastructure literature addresses this tension. Monteiro et al. (2013, p. 576) characterise information infrastructures as

> 'modules/systems (i.e. multiplicity of purposes, agendas, strategies), dynamically evolving portfolios of (an ecosystem of) systems and shaped by an installed base of existing systems and practices (thus restricting the scope of design, as traditionally conceived). [Information infrastructures] are also typically stretched across space and time: they are shaped and used across many different locales and endure over long periods (decades rather than years).'

Infrastructure projects challenge conventional notions of design that assume clear and stable borders (between the designer and the user, the problem and the solution, management and practice, etc.) and the ability to prespecify problems and select from pre-existing packaged solutions (Garud et al. 2008). In infrastructure projects, this is simply not the case. Rather, there are continuously emerging networks of social and technical elements, and problems and solutions dynamically emerge and change in the problem-solving practice (Bossen and Markussen 2010). An information infrastructure therefore analytically 'de-emphasizes things or people as simply causal factors in the development of such systems; rather, changes in infrastructural relations become central' (Star and Ruhleder 1996, p. 113). A key analytical priority of examining a phenomenon as infrastructure therefore lies in detecting what is supporting the work of others and who is sustaining those relationships (Ribes and Lee 2010).

2.2 Articulation work, infrastructuring, and repair

We therefore consider the changes in infrastructural relations (Star and Ruhleder 1996) that emerge in the infrastructure project. In Computer-supported cooperative work (CSCW), the concept of articulation work has enabled insights into such relations (Strauss 1988). *Articulation work* is understood as 'work that gets things back "on track" in the face of the unexpected and modifies action to accommodate unanticipated contingencies' (Star and Strauss 1999, p. 10). Articulation activities have an invisible character because they 'are extraneous to the activities that contribute directly to fashioning the product or service and meeting requirements' (Schmidt and Bannon 1992, p. 8).

Information infrastructure studies have traditionally conceptualised articulation work as invisible work that typically becomes noticeable when the infrastructure breaks down (Star and Ruhleder 1996). Although a working infrastructure should be transparent, it is contingent on the infrastructure project to make problems of use visible (Neumann and Star 1996; Star and Bowker 2002). Articulation work in infrastructure projects therefore extends problems of use into the heterogeneous relations involved in large-scale, long-term, and interdisciplinary infrastructure projects. These relations spawn many and diverse tensions (Ribes and Lee 2010), including aligning the end goals of several participants, different reward structures, the different practices and methods involved, and divergent standards and regulations. Recent work in *infrastructuring* has engaged with such a wider, relational, and in-the-making perspective on infrastructures (Karasti and Baker 2004). Karasti et al. (2010), for example, show how information managers tasked with managing technology over the long term balance the concerns for ongoing, reliable, and sustainable information environments, towards short-term and project-specific goals.

Participants in infrastructuring consequently attempt to strike a balance between the demands of the present and a desired future (Ribes and Finholt 2009). Infrastructuring studies have shown how the tension between local needs and global strategies can be balanced by creating laboratories for experimenting (Parmiggiani et al. 2015), how material 'ordering devices' enable and shape practices (Bossen and Markussen 2010), and how incremental methods and user participation are essential to infrastructuring (Pipek and Wulf 2009). Ribes and Polk (2014) advocate an ecological approach to infrastructure change, according to which the sociotechnical facet of change (i.e., change in work practice, coordination, and collaboration tools) is considered in relation to 'technoscientific change' (i.e., changes in the objectives and methods of the infrastructure) and 'institutional change' (i.e., changes in funding and regulations). Technoscientific and institutional change are less studied, but understanding them is essential to a full grasp of the tensions involved in infrastructure change. As Bødker and collaborators maintain, infrastructuring consists of a 'diverse set of design activities on many organizational levels, revolving around technology, decision-making, competence building, commitment, and policy-making' (Bødker et al. 2017, p. 246).

Here, we apply such an ecological perspective to infrastructuring. The ecological approach sheds light on the relations between changes at the sociotechnical level and diverse actors, organisations, objectives, methods, and regulations as they are engaged and changed in the infrastructure project. Extending the traditional scope of a technology project, this perspective includes several different departments and management levels within the municipality, cooperation between the municipality and several vendors, cooperation between vendors and subvendors, different technologies (new and existing), various cooperation agreements and contracts, and governmental procurement regulations and implementation standards. We discuss how infrastructuring, as a result of including and relating these different facets of change, gives rise to ambiguity that needs to be managed.

To analyse how ambiguity is managed, we draw on recent literature on *repair*. Three aspects of repair are relevant to our analysis. First, repair is not only about keeping infrastructures from breaking; it is also considered generative, because it is 'precisely in moments of breakdown that we learn to see and engage our technologies in new and sometimes surprising ways' (Jackson 2014, p. 230). The phenomenon of repair adds to distinct broken–fixed dichotomies and emphasises that subtle and ongoing acts of breaking and repairing are foundational to innovation in infrastructures. Furthermore, in line with infrastructuring, studies of repair, instead of focusing solely on fixing technology per se, consider the extended range of social and technical actors and activities that shape the technology in an attempt to understand the kind of work to which breakdowns give rise (Larkin 2013). Second, breakdowns and repair activities are difficult to plan in advance, so collaborative repair work is contingent on the particularities of breakdowns as they unfold in the infrastructure project, and it occasions ongoing and contingent processes of valuation that can never be fully planned for in advance (Rosner and Ames 2014; Houston et al. 2016). Finally, studies of repair focus on how both maintaining ageing technologies and innovating new ones require an engaged care relationship with technology (Jackson 2014) on behalf of a widened array of actors involved in infrastructuring.

The generative, contingent, and care perspectives on repair are relevant to our examination of the implementation of a new surveillance infrastructure. The surveillance system is embedded into existing systems and practices at health and welfare centres. It is highly relevant to practice, because staffing is a function of economy and the surveillance system. The system therefore quite directly shapes, and must be shaped by practice. Simultaneously, it embodies several standards, such as governmental procurement processes, and packaged software. Moving beyond how the surveillance infrastructure is appropriated by practitioners, this study focuses on the infrastructure project's implementation phase, when change is negotiated among a larger group of stakeholders, choices and adaptations can still be made, and through ongoing steps of breakdown and repair, the ambiguity of the project is made manageable enough to proceed.

3 Case and Method

3.1 Case background: Welfare technologies

This paper is based on parts of an ongoing longitudinal case study of welfare technology [1] in a large Norwegian municipality (178,000 citizens). The municipality aims to make welfare technology an integral part of its service offering by 2020. Welfare technology, which is designed to alleviate some of the pressure on health and welfare services, aims to prevent falls and mitigate loneliness and cognitive decline. We were granted access to the case through the municipality´s welfare technology program (henceforth referred to as 'the VT program'). The municipality's 'theme plan for ICT, digitalisation and welfare technology (2015–2018)' (henceforth referred to as 'theme plan') characterises the VT program with the motto 'safe where you are'. The program's goal is to deliver welfare technology services to citizens in the municipality—independent of age, level of independence, and place of residence—when such services are believed to contribute to increased empowerment and safety.

3.2 The surveillance system

Our research team was asked by the VT program to look into a particular health and welfare centre.[2] This centre was the second of a total of 36 health and welfare centres that will receive a new surveillance system within 2020. The introduction of the surveillance system in this centre had caused some concern, which was part of the reason for the VT program's involvement of researchers.

The new surveillance system is used for communication between centre employees and residents. The system consists of a number of physical artefacts, such as mobile artefacts, wearable artefacts, and artefacts embedded into the building infrastructure (see Figure 1). Wearable artefacts include pendant and

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[1] 'Welfare technology' (also known as assistive technology or care technology) is a term used in Norway to describe technologies that aim to ease the potential burden of the ageing society.

[2] A health and welfare centre is a combined nursing home and residential care facility in which efforts are made to move away from institutional characteristics and implement enjoyable, real-life conditions for residents.

wrist alarm units worn by the residents. They enable the residents to send an alarm signal to the employees when they need help. They also include Radio-frequency identification (RFID) tags that residents use to unlock the door to their rooms. Embedded artefacts include room communication units and door locks. Room communication units allow employees to establish a two-way voice link with a resident's room when, for example, the resident initiates an alarm. Door locks are used to automatically lock and open the doors to residents' rooms using RFID tags (this is to prevent residents with severe dementia from entering other residents' rooms). Employees have access to two types of mobile artefacts. RFID-enabled employee tags are used to open locked doors and to identify the employee. Dect phone units are used to receive, view, and reset alarms initiated by the residents.

The surveillance system consists of a large 'back-end' part that starts from the wiring and physical building installations (e.g., gateways, access points) and includes remote infrastructures such as the existing telecom backbone (used to connect the Dect phone units), alarm logics management (e.g., programming and personalisation of alarm forwarding), call centres, and ambulatory services (in cases where alarms are escalated into more specialised healthcare-related scenarios).

Figure 1. The digital and physical infrastructure of the surveillance system.

The new surveillance system was implemented to replace the ageing analogue patient alert systems. There were three different traditional pull cord alarm systems in use throughout the municipality. There were several reasons for introducing the new surveillance system. The theme plan shows that 60% of the old infrastructure for patient alerts is ageing. It is no longer possible to find spare parts and technical support for this infrastructure, and this represents a real risk to the operational stability of the existing health and welfare centres.

The surveillance system has different goals for different user groups. First, residents in the care and welfare centres have complex health challenges. The majority of the patients—a full 80%—have dementia or other forms of cognitive decline. The municipality's goal is to adapt the surroundings of people with dementia to the stages of the disease and to adapt services according to residents' individual needs and level of functioning. Residents frequently need to contact care personnel for help, and the system is designed to enhance the residents' experience of safety and empowerment. Residents are to be granted individual access to different areas at the health and welfare centres based on an assessment of what provides the most empowerment and safety. They receive an alarm necklace that can be used for alerting staff as well as for indoor localisation and access. Residents' rooms have smart doors for increased safety; the door opens only for care personnel and the user with the corresponding necklace. Second, the goal for care personnel is to improve the quality and workflow of services and to bring them closer to the residents in terms of better oversight and the capacity for two-way communication via phone directly to the residents' rooms. Alerts are directed directly to the phones of care personnel in order to avoid 'public' alarms, which leads to calmer departments. Third, at the municipality management level, the goal of the surveillance system is to improve the use of resources and the effectiveness of services.

The surveillance system has been a long time coming. The procurement process started in 2001, and it was run for a long time by the department for security and internal control, an audit practice within the municipality. Requirements were gathered in 2002, based largely on experiences with the pull cord system in use at one nursing home in the municipality. In 2012, the process was taken over by the municipality's IT department, and a public procurement process was initiated. A framework agreement was established with vendors in 2013, at which point a packaged software solution was chosen. Although the technology was developed in other countries, it was to be implemented and adapted by Norwegian vendors.

3.3 Data collection and analysis

All three authors were involved in every stage of the research project, including data collection, analysis, and the writing of the paper. Data was collected from different phases of the infrastructure project across four health and welfare centres. At two of these centres, the project was in the maintenance phase (i.e., the system was installed and in use); at the other two, it was in the implementation phase.

Several different data sources were used. First, we engaged in participatory observation of different stages of the infrastructure project. Two workshops were arranged by the VT program at a health and welfare centre where the system was being implemented. These workshops included the centre leader, care providers, vendors, and the welfare technology program; they involved a total of 12 people. Two additional workshops were held at a centre where the system was in use. The purpose of these workshops was to establish a common understanding of certain problems and to fix them, and they involved 20 people, including centre leaders, VT program representatives, care providers, and different vendors. We also took field trips to health and welfare centres where the system had been implemented in order to see the surveillance system in use, and we explored a demonstration room (which one of the health and welfare centres had set up to demonstrate, test, and evaluate new technologies). We also visited residents at one of the centres. Written notes and photographs were taken during the field visits. Meeting minutes and notes were taken during the workshops, and they reflected the observations of discussions between key actors in the infrastructure project. Second, we conducted 10 interviews. Respondents included residents, care providers, centre leaders, staff from the welfare technology program, and the municipal IT department. Interviews were recorded, and transcribed. Third, we relied on documents provided to us by the municipality. These included internal documents concerning strategy, requirements, testing, organisation, and experiences from use (including errors and plan for improvements). We surveyed public documents in the form of program statements and strategies for welfare technology and analysed the available training material created for the surveillance infrastructure.

We adopted an interpretative approach to our data analysis (Walsham 2006), and our central concern was how the actors involved perceived the infrastructure project. In accordance with Klein and Myer´s (1999) principle of dialogical reasoning, our theoretical knowledge necessarily affected how we understood the phenomenon under investigation. From the outset, therefore, we considered the surveillance system an example of information infrastructure. However, particularly with respect to the two health and welfare centres that had already installed the system, the data indicated that the new system was breaking in different ways, and it pointed to the characteristics of and reasons for the breakages. It was when these findings were presented to the municipal VT program that we also became aware of all the ongoing activities that were focused on addressing the breakages and how these activities included repairing the infrastructure project itself. Considering the interdependent significance of these repair activities (ibid.), we hypothesised that repair was occurring both for the technology in use and the organisation of the infrastructure project. During our ongoing dialogue with the VT program, we were invited to analyse how repair was unfolding at other health and welfare sites, in collaboration with vendors, the site practice, and the VT program. Our selection of sites was therefore based on a combination of practical issues and analytical interest. The selection was practical because it allowed us to study sites where the infrastructure was already in use as well as sites where the infrastructure was still being implemented. Our ecological approach to infrastructuring, which highlighted different facets of change, inspired us to study not only the infrastructure in use but also the various phases of its implementation.

As Ribes (2014) argues, attention to the actors involved in scaling is important in studies of large-scale sociotechnical systems. The researcher places analytical focus on the techniques and tools actors use to manage the scale of their enterprise. Infrastructuring is such an enterprise. Studying these actors, their methods and practices, and their tools allowed us to develop an understanding of the ambiguous repair work occurring in the infrastructure project. Following Blomberg and Karasti (2013), we constructed the field site by selecting and connecting 'the material artifacts and the people who define the field' (p. 389). As we observed and talked to the practitioners involved in infrastructuring, it became clear that the infrastructuring field included 'a multifaceted and intricate constellation of people, technologies, activities, entities and relations' (ibid., p. 388). The literature on infrastructure and change (Ribes and Polk 2014) has demonstrated that such a broadening of the field constitutes an ecological approach to change, including sociotechnical change (in which users become familiarised with the system), technoscientific change (in which the goals, methods, and practices of the project are established), and institutional change (in which regulations and standards are developed). The combination of all these facets of change in the infrastructure project caused ambiguity, and we were able to study the actors actively dealing with it.

We made additional observations when we began to detail the repair mechanisms involved in dealing with the ambiguity of the infrastructure project. The municipality provided us with documents relevant to the challenges the project was facing during system implementation, including descriptions of how those challenges were mitigated. We alternated between data collection and analysis. Data was coded and categorised by the first author, and the analysis was critiqued and refined through discussions with the second and third author. We also conducted a dialogue with the field and received comments on our findings.

The analysis revealed the presence of three interconnected repair mechanisms. It is challenging to draw distinct borders between interconnected mechanisms, because they are contingent on each other and can occur at various times throughout the infrastructuring project. Repairing the value-network, for example, spurred the creation of a new and improved process, which in turn spurred participation. We separate these mechanisms analytically because each of them represents an important element of the process of repair in infrastructuring. First, value-network repair is concerned with how sociotechnical challenges—i.e., problems with the new infrastructure in use—stimulated changes in relationships within different departments of the municipality and between the municipality and external organisations. We use the term 'value-network' to signify how the project network of actors changed from originally being designed for sharing concrete results or artefacts (e.g., requirement specifications, components and systems) towards focusing on the continuous sharing of insights, troubles, experiences, challenges, and knowledge. Second, the repaired value network was more sensitive to how the high-level, governmentally standardised implementation process failed to work for some actors in the network (notably the care practitioners), and importantly, it implemented new, more iterative processes intended to educate end users and involve them in the shaping of the technology. Third, participation repair indicates how material artefacts played a significant role in the iterative processes and helped care practitioners link their practices with practices used at health and welfare centres where the infrastructure had been implemented.

4 Findings

In this section, we empirically illustrate the three interconnected repair mechanisms we identified in the case study. Each mechanism describes challenges the project faced, and the contingent and collaborative project work that was required to address those challenges.

4.1 Value-network repair

When we began the case study, the two care and welfare centres that had implemented the system were facing multiple challenges in using it. There were problems with coverage for the phones, because the building infrastructure did not have sufficient room for the necessary cabling. The alarms had presented several challenges. When an assistance alarm was triggered to indicate that a care worker needed assistance, only the care worker's position, not his or her identity, was shown. However, the care workers wanted to see who triggered the alarm in order to increase awareness. The sound of the alarms was a problem at night. Alarms would override the silent setting on the phones, so when a care worker was in a resident's room when an alarm was triggered, the alarm woke the resident. A more severe problem concerned the automatic acknowledgement of alarms through the employee identification tag. The alarm's configuration had the unintended consequence that it would automatically be registered as acknowledged when a care provider merely walked passed the room, not attending to the resident. Because this configuration of the feature could put residents' health at risk, it led to the decision to turn off the automatic acknowledgement completely.

A key challenge for the project at this stage was that these issues had not been detected and acted upon before or even during the implementation of the surveillance system. Evaluations of the project during this period indicated that there was a lack of monitoring at implementation sites, that many meetings between the municipality and vendors were ineffective because of a lack of insight into actual progress, and that these factors in combination negatively influenced the time and economy of the project. It was also recognised that a malfunctioning alarm system could endanger the health of residents.

> 'This influences the economy of the project, especially in terms of time used. If the project is not properly coordinated, we could end up with the wrong solution, as a result of which the repair costs will be even greater.' (Project documents)

Clearly, the municipality did not bear sole responsibility for this situation. A contractual mechanism between the vendors and the municipality was formulated in a way that led the vendors to work on changes and improvements without coordinating with the municipal representatives involved in the project. Furthermore, there was initial confusion with regard to how and where the health and welfare practices should report system errors. For example, some errors were reported through the deviation management system instead of through the IT support system, so these error messages did not reach the infrastructure project.

Clearer criteria had to be established to indicate when the infrastructure was under development and when it was operational. Issues such as what should be billed to which organisation (the infrastructure project or the health and welfare centre), what should be categorised as a bug fix, what should be considered a new functionality, and what should be considered an improvement had to be worked out. To manage such issues, and to enable informed decisions, a working group was formed that sought to include all relevant stakeholders in the project. The director of health, who represented municipal management, was responsible for ensuring that decisions were made and necessary approvals were granted and was particularly concerned with achieving the defined value realisations within the budgeted time and cost. The municipal IT department was responsible for interfacing with the vendors, who were organised as a separate project. The VT program (organised under the municipal health department) was responsible for including users and testing, for ensuring that the users' performance and functionality requirements were confirmed, for ensuring that the health and welfare centre made sufficient resources available to the implementation project, and for the production of training material. The municipal department for security and internal control shared this responsibility with the VT program. The representative of the municipality's property department was responsible for coordinating the work on building infrastructure at the centres. The working group met for one and a half hours every 14 days. Figure 2 depicts the emerging value network.

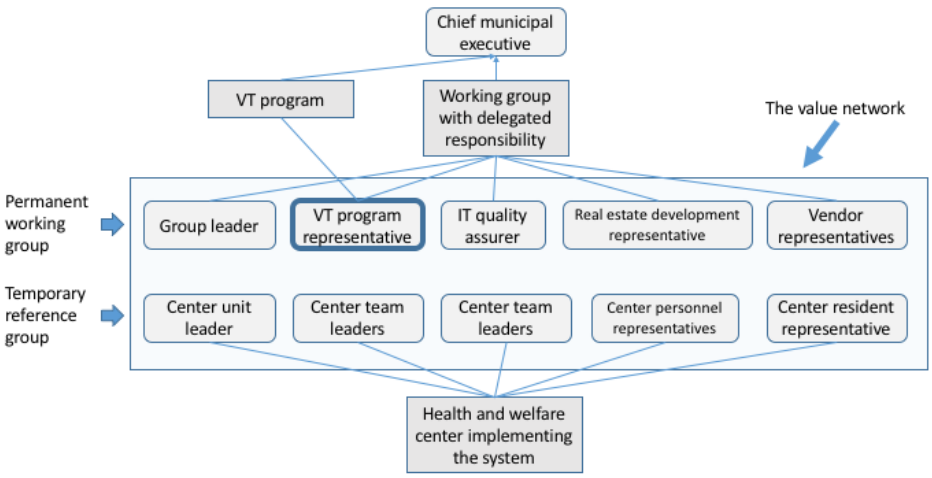

Figure 2. The emerging value network.

The representative from the VT program was pleased with the working group, particularly as a mechanism for improving relationships among project members:

> 'It is more systematic now, we make shared decisions, and we are in tune with the municipality regarding what constraints we will operate under. I

> get continuous feedback from the sites. They have begun to think about needs and solutions, and they can now think about improvements. The working group gives us some leverage with the vendors, because it brings me closer to those who are responsible for the decisions. I often have the minutes from the working group meetings, and use this, and I and [name of IT representative] address the results from the working group meeting with the vendors.' (Interview, VT program representative)

Adjacent to the working group was the reference group, which consisted of leaders from three health and welfare centres, two team leaders, health workers, and one resident. Formally, 'the work group is to coordinate with the reference group before decisions are made' (Project documents). Equally important was that the VT representative, acting as the user representative in the working group, used the reference group to add leverage to the requirements and needs arising from practice. Problems reported by a single site were given less weight than those reported by the reference group, because the reference group was considered a representative of the sites collectively.

When the infrastructure project started at a site, the roles of some of the care staff changed—they became key resources for the implementation project. One such role was as a 'super user' (their term for a user that shouldered a specific responsibility for working with the infrastructure project), who acted as the on-site 'glue' between the project and the practice.

> '[A vendor representative] insists there must be more super users. There need to be at least two from each care department at the health and welfare centre. This is key to the proper management of training and testing. The health and welfare centre had managed to recruit three.' (Field notes from order meeting at a health and welfare centre)

In addition to playing key roles in ordering, specifying, testing, and training, these super users assumed the role of serving as a link between the vendors, the project, and the day-to-day operations, especially in terms of reporting errors and bugs. However, when care personnel reported errors, they did so typically at the end of the day, because they simply did not have time for it during daily operations. After the error message travelled across the municipal IT support team and finally reached the vendors, they would have problems replicating the error—and it was challenging to get in touch with the person who had originally reported the error. The super users were therefore tasked with collecting system errors from the staff, reporting them in a coherent way to the vendors, and being available to the vendors for communication as they tried to fix the error. Recruiting super users proved to be challenging, because care workers saw this role as a new and additional task. One super user stated that the role should come with an increase in salary, because it was considered an addition to the daily work care staff were already doing.

The VT program representative was assigned the task of following the implementation process from welfare centre to welfare centre and of ensuring continuity and experience sharing between the centres. She was therefore actively involved in informing new sites of the experiences of other sites and making sure that the key lessons learned at previous centres were communicated to those responsible for the new implementation projects.

> 'There was a discussion about the routing of assistance alarms and how much delay there should be between when an alarm goes off at a care department and when it is escalated to other care departments (if it goes unanswered). One of the nurses/super users turned to the VT representative and asked, "How do they do it at [the other centre]?" "There, they use [a delay time of] 30 seconds", the VT representative answered. "OK, we will do that as well", the super user answered.' (Field notes)

The VT representative learned the language of both the vendors and the health and welfare centres and gained the ability to recognise misunderstandings in meetings and clarify issues as needed. An example of how intimately she knew the process and the language was observed in a meeting at which vendors and care personnel discussed the position of a sensor:

> '[The vendor representative] was unable to locate the icon for the emergency opener switch. The VT representative leaned over and showed him the icon. "It is called a backup panel", she said. [The vendor representative] laughed and said, "You can take over my job now".' (Field notes)

4.2 Process repair

Several factors contributed to standardised and top-down processes. First, the procurement of the surveillance system began in 2001, and it was initially coordinated by the department for security and internal control. The IT department took over, or in their words 'made a coup of the process' (Interview, IT department), in 2012. When the IT department became involved, it strengthened the focus on governmentally defined standard agreements. Moreover, the focus shifted, quite understandably, to the administration and maintenance of all the municipality's alarm services. 'In reality, there was only one vendor' (Interview, IT department) that could be chosen, because only one vendor had the ability to administer all three alarm solutions in use by the municipality.

Another factor that contributed to standardisation was that public IT procurement projects in Norway must adhere to a five-phase implementation process.[3] The first of these is the concept phase, during which an idea is described, its socioeconomic value is analysed, and a project description is made. The second is the planning phase, during which an execution strategy is devised, changes in work processes are described, and a benefits-realisation plan is established. During the execution phase, contracts with vendors are signed, training activities are undertaken, and the product is delivered to the practice. Subsequently, in the finishing phase, problems and errors are addressed, contracts are closed, and project evaluation takes place. Finally, in the benefits-realisation phase, the benefits of the IT investments are measured and managed.

Third, the nature of the patient surveillance system prohibited it from iterative and bottom up-implementation. Implementation here was very different from that of an app, in which case you can iteratively launch the

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[3] www.prosjektveiviseren.no (accessed 30.08.2017)

minimum viable product and learn. Here, doors needed to change, wiring in the ceiling needed upgrading, alert routing had to be established, and work processes had to be changed. Installation of this system lasted for an extensive period of time and demanded planning, such as that related to where residents would live while their door was changed and how much more staffing was necessary when the existing surveillance system was down.

Having well-defined plans and processes was therefore understandable. The challenge was that it did not produce working solutions in practice. The working group (in the value network) consequently assigned the VT representative to develop a 'Handbook for Implementing the Patient Surveillance System'. This handbook documented the process the VT program used to improve information flow, structure, coordination, and responsibilities between actors in the project.

In fact, a more iterative process was established within the framework of the high-level processes. A key ingredient was the transfer of as much learning as possible from previous sites into the next one and the introduction of arenas for dialogue and learning between vendors and the practice. Although the governmental process can work on a high level of abstraction and can formulate framework agreements with vendors, the municipality needed a process that would align with the practical concerns at each of the 36 health and welfare centres that were implementing the new system.

The new process had three main phases: planning, execution, and implementation. The sequence of the phases, their purpose, and who participated in them are detailed in Tables 1, 2 and 3.

Table 1. Punctuation in the planning phase.

	Purpose	**Participants**
Information letter	- Describe goals. - What the project implies. - Plan.	- Letter sent from work group to centre.
Needs meeting	- Understand needs of residents, care workers, and visitors. - Map the building infrastructure.	- The centre, VT program, department for security and internal control, advisor to the councilman.
Information	- Present the technology.	- The centre, the work

meeting	- Consider needs vs. technology. - Manage expectations. - Plan for implementation in accordance with daily operations.	group, and vendors.
Ordering meeting	- Select from technology offering. - Go through plan drawings for the building infrastructure. - Specify phone solution. - Enrol super users. - Joint inspection of the building.	- The centre, vendors, work group.
Verification meeting	- Centre confirms that the specified solution is in accordance with their needs. - Specifications sent from vendors to municipal department for property.	- The centre, vendors, work group.

Table 2. Punctuation in the execution phase.

	Purpose	**Participants**
Planning	- Plan upgrade of building. - Project description (building) prepared for public procurement processes. - Plan for installation of surveillance system.	- The centre, vendors, department for property, IT department, VT program
Risk and vulnerability analysis	- Risk and vulnerability analysis pre-installation.	- The centre, vendors, VT program.
Needs	- Register individual needs per resident. - Training in making design decisions according to Norwegian patient laws.	- The centre, vendors, VT program.
Progress and status	- Status meetings. - Check project organisation, status, and deadlines. - Detect deviations and report to work group.	- The centre, vendors, work group, VT program.

Table 3. Punctuation in the implementation phase.

	Purpose	Participants
Training	- Digital training materials with certification program. - Hands-on training provided by vendors.	- The centre, vendors, department for security and internal control, VT program.
Acceptance test	- Vendor does site acceptance test. - VT program performs and approves acceptance test before and after deployment of the system.	The centre, work group, vendors, VT program.
Maintenance	- Errors and needs for improvement reported to municipal IT support. - New additional products ordered.	- The centre, municipal IT support.
Evaluation meeting	- Evaluating the process, what worked well and what could have been done differently. - Plan necessary follow ups.	- Work group, vendors, the centre.

The process outlined above is to be implemented 36 times before the infrastructure is complete, once for each health and welfare centre in the municipality. Some of the actors involved in the processes will change, such as managers and super users at the health and welfare centres. Some will remain, however, such as the working group, the VT program, and the vendors. New actors are enrolled at each new site. The process aims to inform, prepare, and engage users, learn from experience, and follow up the implementation and its effects.

We observed the operation of this process. As an example of dialogue and learning, consider the following excerpt from our field notes from an order meeting in which the handling of alarms was discussed:

> 'One of the care workers wondered what the alarms would look like on the new phones: "Will they appear as an unanswered message?" The VT program representative said they would appear as a "new task". The care

> worker said, “I just want to make sure that the alarm is not missed, that someone addresses the alarm”. A vendor representative drew attention to the Excel spreadsheet that specifies the alarm routing and the alarm-escalation steps. He also explained that there is automatic receipt of alarms when a care worker stays for one minute at the same location as the resident that sent the alarm. The care worker said, “That is fantastic; we often work with gloves on”. The VT representative said, “From our experiences at [the previous centre], we use automatic receipt only from the room units, not from the public areas”. The representative from department for internal control and security said, “Those who have taken this path before you can relate some of their experiences”’. (Field notes)

This excerpt illustrates the cooperation between vendors, the work program, and the health and welfare centre in addressing specific issues in the process of that particular centre. It also illustrates that experiences from previous sites are used by both vendors and the VT program to guide the current process.

4.3 Participation repair

As we have shown, the surveillance system is challenging to implement according to the incremental ideal. Furthermore, the requirements that were used in the procurement process were based on experiences with an older alarm system collected at one health and welfare centre in 2002. The requirements were rather ‘abstract requirements related to needs’ (Interview, municipal IT), and as the VT representative told us, the choice of technology is more ‘in accordance with what has happened on the market side’ (Interview, VT program) than with current user needs. In sum, there were several factors constraining the level of participation of users in the shaping of the infrastructure.

Still, there was created room to manoeuvre in order to fit the packaged solutions to practice. Because we participated in information, ordering, and verification meetings, we observed how artefacts were used in a collaborative tailoring of the surveillance system. As Figure 3 illustrates, vendor-created schemas were used to specify the alarm routing.

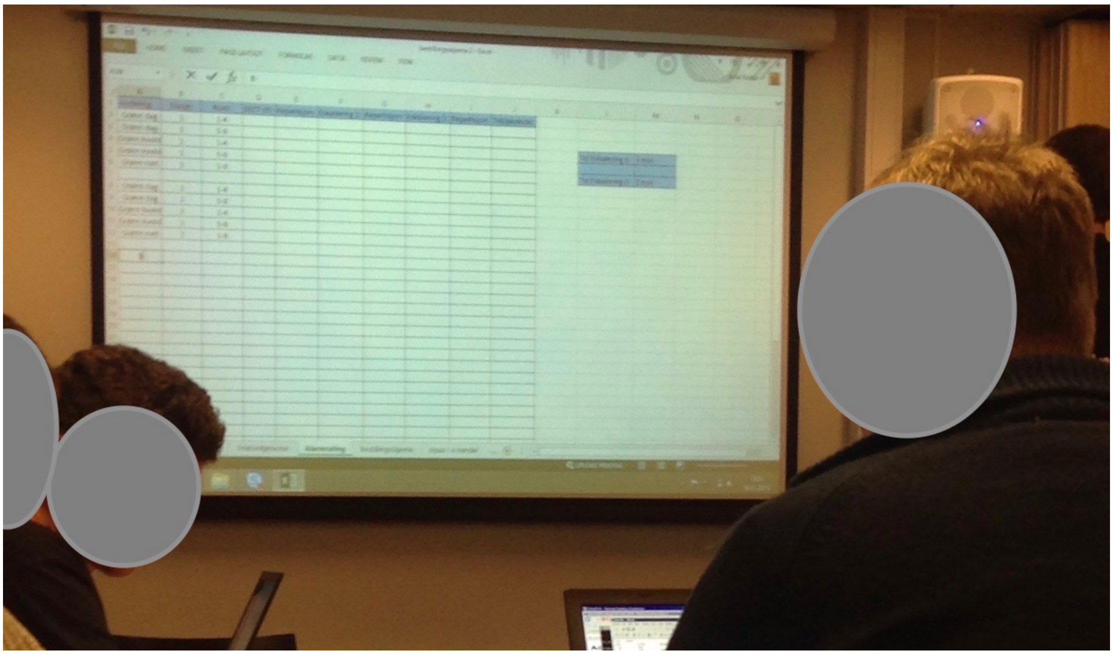

Figure 3. Collaborative definition of alarm routing.

We sat in on a meeting in which the project group at the health and welfare centre had been given the schema before the meeting and had discussed how they wanted the routing to operate.

> '[Team leader] said, "How the nursing teams are organised varies. But the rule is that it should not take more than five minutes to respond after an alarm is sent". [VT representative] said, "At [another centre], they have reduced the escalation time to one minute before the alarm is sent to other teams". [Team leader] said, "So how do we want it? Is it not OK just to stay with the procedure we use today? It is beneficial to have the same practice across all care departments at the centre". [Representative for the department of security and internal control] said, "That is right; if you have something that works, don't change it. This is the way it is, and this is the way we want it". The discussion of alarm routing went on to address at what level the responsible nurse should be in the alarm-escalation procedure. Then the team leader, a bit overwhelmed with the details of the discussion, stated, "Is it possible to change this setup if need

be?” The VT representative answered, “Yes, we have verification, and we have acceptance tests. After that, however, you can still change, but then your department will incur the cost”’. (Field notes)

As this excerpt shows, the topic of alarm routing triggered a discussion about how they should work with the future system across different teams at the health and welfare centre. At this point, they could not fully know how the infrastructure would work in practice, but the routing design helped them reflect on certain possibilities. They also drew on the experiences of the VT program representative who had accumulated experience at other sites. The implications of the system became more visible, indicated by the team leaders’ concern regarding the reversibility of the decisions made at the meeting.

The infrastructure seemed to become more tangible for the users as they worked with the artefacts representing it. The field notes excerpted below illustrate that they learned about the technology as they determined the placement of sensors in the building (see Figure 4). They discussed where to put the localisation tags and how they should be identified to make sense in practice (e.g., ‘kitchen’). They discussed different scenarios, such as which doors needed to be smart doors and part of the infrastructure project and which doors should simply have burglar alarms.

‘They started to discuss a particular problem: many of the employee identification tags were disappearing along with the dirty laundry (the care staff forgot to take the units off before disposing of the laundry). Because this was a problem across several centres, the vendor created a “dirty laundry alarm” that detects when an identification tag is tossed into the dirty laundry. They began to discuss whether the alarm would be triggered simply by being in the washing room and whether this would be a problem. The vendor explained, “No, that would not be the case; this alarm uses LF [low frequency]”. The team leader asked, “What is LF?” The vendor explained, “LF senses in very close proximity. As opposed to IR [infrared], which we use for room positioning, LF is used to open doors and get the signal immediately, and we can adjust the distance very accurately. We also do not send the dirty laundry alarm to all the phones; it is a local alarm in the laundry room that beeps there, and it stops beeping if the care unit leaves the sensing zone"'. (Field notes)

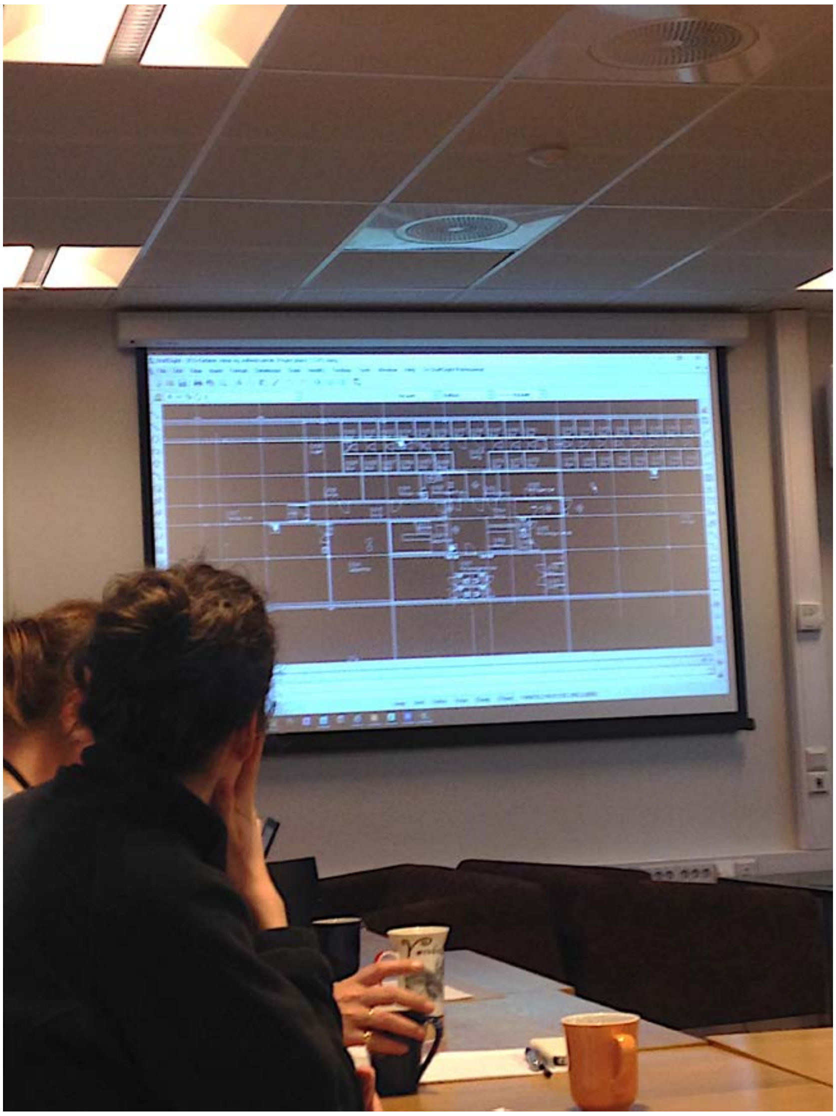

Figure 4. Collaborative mapping of sensors to both the floor plan and practice at a health and welfare centre.

5 Discussion

As digitalisation projects in the health and welfare sector move from pilots to infrastructures, the infrastructure project becomes a significant agent of change. Infrastructuring has to deal with uncertainty on two levels. First, there is sociotechnical uncertainty with regard to the technology working across several different practices. Second, there is uncertainty about how infrastructuring should be organised to deliver working infrastructures. Taken together, these uncertainties give rise to ambiguity, which is notoriously difficult to plan for. Motivated by our research question—How does an infrastructure project move forward productively in the midst of ambiguity?—we have conducted an interpretative case study of the implementation of a surveillance infrastructure in a large Norwegian municipality. Our findings reflect an ecological perspective on infrastructuring: they encompass a broad value network of organisations and practices, the processes and methods involved, and the participation of different users (Ribes and Polk 2014). Our analysis indicates that the generative, contingent, and care characteristics of the repair mechanisms are necessary for dealing with the ambiguity of the infrastructure project. Table 4 summarises the challenges in the project and the repair mechanisms used to deal with them.

Table 4. Infrastructuring as ambiguous repair.

Repair mechanisms	**Challenges in infrastructure projects**	**Repairing the infrastructure project**
Value-network repair	- Distinct boundaries - Vendors provide technology, municipality consumes it - Vendor–municipal management dialogue (framework agreement) - Users outside the loop	- Establish working group of vendors, municipal management, VT program, users - Establish user forum, give weight and relevance to requirements - VT program representative ensures continuity across implementation sites - Centre leaders became site project leaders - Nurses became super users - Collaboration to co-create value
Process repair	- High-level, governmental waterfall process - Clear boundaries between phases - Predefined value-realisation plans	- Finer-grained processes within the framework of the high-level process - Value and valuation is negotiated between vendors, management, and users - Networks of valuation emergent and changing
Participation repair	- Commodity view at municipality - Backbone architecture focus (maintenance of infrastructure)	- Material artefacts spur reflections on current practice, future infrastructure practice, and learning across sites - Participation by shaping that

	- Third-party packaged solutions, local vendors	which can be shaped - Motivation and engagement as implications for practice become evident through material artefacts

Using insights drawn from the three repair mechanisms, we find that repair is generative in infrastructuring. Infrastructuring studies have shown how projects create networks of collaboration across time and space and that such collaborations require the support of a network of human and technical actors, such as data managers and systems administrators (Karasti and Baker 2004; Karasti et al. 2010). We find that in the formative stages in infrastructuring, it is necessary to grasp the breadth of relations in the infrastructure project's value network, that is, the way the project ties into and create a 'knotwork' of 'existing networks and systems across organisations, and how agency and initiatives become dispersed within these networks' (Bødker et al. 2017, p. 248). In this case, the network consisted of several municipal departments (real estate, IT, health, internal control), several health and welfare centre practices, different management levels, and vendors and subvendors. Particularly relevant to infrastructuring is *how* these different organisations come to support each other, that is, how they become a working value network.

We find that this did not happen by design. Quite to the contrary: our findings indicate that the original and designed infrastructuring network was breaking. It was based on the notions of clear boundaries between the municipality and the vendors, stable preferences specified in contract and value realisation plans, and fixed goals. Garud et al. (2008) argue that such traditional notions of design rest on a naïve belief in the virtues of completeness and are unable to capture how the unfolding of design projects in practice changes the very problem the projects are attempting to solve. Our findings indicate that the initial rigidity of the network undermined the infrastructure project´s ability to deliver a working infrastructure that reflected the changes that occurred as the project unfolded. The choice of distinct borders rested on the expectation that the vendors would simply deliver and install working solutions. One health and welfare centre leader commented on her lack of involvement with the project: 'I just want it to work' (Field notes). The municipality considered the infrastructure a commodity, not recognising the degree of change, commitment, and care the infrastructure project required from them. Moreover, internally in the municipality, there was a lack of collaboration between those managing the project and the practices where the surveillance system was to be used, exemplified by the procurement's being grounded on requirements established a decade before. As the sociotechnical failures of the system-in-use emerged, they occasioned a change in the relationships that comprised the project value-network. The repair process included the formation of new relationships in the value networks, as reflected by the creation of working groups and user forums.

Generativity from the repaired networks required people to change and extend their existing roles and responsibilities (Ribes and Polk 2014). We find that the health and welfare centre leaders, in addition to leading the day-to-day management of the centre, became local project managers dealing with the day-to-day implementation of the infrastructure. Nurses became super users, tasked with training others. The VT program representative gained the ability to translate between the language of vendors and users. Such changes meant that users met designers halfway by learning their language and developing an understanding of design (Star and Ruhleder 1996). The converse was true as well: the designers had to learn the language of the users. Importantly, we find, this came at a cost. The healthcare workers were busy working on their core tasks, so infrastructure projects should allocate time and resources for care leaders to take on the role of project leaders and healthcare workers to take on the role of super users. As one care worker who was also a super user told us, it is difficult to report error messages while you are changing diapers.

Although both the invisibility of infrastructure (Star and Ruhleder 1996) and the development of a common language (Neumann and Star 1996) are at play here, we find that there were also more mundane breakages in infrastructuring. Contractual arrangements led vendors to work on problems at the health and welfare centres without informing municipal project management, and the lack of unified error-reporting methods led to the occurrence of undetected problems in the care practice. Repairing these breakdowns required establishing a value network that involved broader groups of actors (indicated by the establishing of the user forum, for instance), had decision-making capabilities (as a result of including the top management in the municipality), and met continuously. The more inclusive value network allowed for a realistic and negotiated identification of what a break was (Rosner and Ames 2014). We do not suggest that such networks necessarily solve or work out all the tensions of a project, but they increase the likelihood of detecting mundane breakdowns and working collaboratively to fix them (Larkin 2013; Jackson 2014). A key capability of the emerging value network is that it creates relationships by allowing insights, knowledge, and experience to be shared between the sociotechnical facet (including user forums and vendors) and other facets (such as decision makers with economic responsibility for the project).

The repaired value network tailored the high-level governmentally defined implementation process to a more contingent valuation process. Many studies of infrastructure begin by reiterating Star and Ruhleder´s (1996) assertion that infrastructure is invisible until it breaks down. Importantly, however, visibility depends on perspective, and 'one person's infrastructure is another's topic, or difficulty' (Star 1999, p. 380). The high-level implementation process was working (i.e., invisible) for the IT department, which got the contract into a form that was suitable for them, and ensured a contract with a vendor that could maintain all the existing alarm systems in the municipality. The vendors were satisfied with addressing errors at the sites. The infrastructure was not working as expected for care workers, however, so the high-level process cannot be considered as working for them. There are good reasons why such high-level processes are needed; for example, they are necessary for doing things similarly across different municipalities in line with best practice and according to legal frameworks. Furthermore, there are many aspects of the implementation of infrastructures that require rigid planning, such as changing doors, installing wiring in the ceiling, and adding staff when door locks are being replaced. In terms of delivering working infrastructure in practice, however, the high-level process was breaking. This was not a catastrophic breakdown, but a break that, once detected, spurred the creation of a process better suited to account for the needs of the users, though still operating within the required framework of high-level processes, plans, and packaged solutions.

Repairing the process then implied improving relations between formal development project initiatives and the 'local repair worlds' (Jackson et al. 2012, p. 114). Practically, this was done by punctuating the high-level process, which created finer-grained iterations that generated arenas for engagement, learning, and local adaptations. These findings resonate with the learning communities Karasti and Baker (2004) find to be important for managing the long-term concerns in infrastructuring, and indicate that these types of collaborative arenas are necessary in infrastructuring projects of various durations. Consider the definition of alarm routing. As defined in the service agreement with residents, a resident in a health and welfare centre must get help within five minutes after pressing the alarm button. If the infrastructure accomplishes this, it is a success. With the repaired process, evaluation of success became more nuanced. This is because alarm routing was negotiated between the technology vendors and the care practice. As care workers collaborated with vendors at several iterations of the process, they got a better grasp of the technology's capabilities. They could assess implications for work, compare these implications in light of experiences from previous sites, and tailor as much as possible of the technology to local needs. These emerging evaluation criteria were nuanced by being grounded not only in formal service level agreements, but also in practice. Adding to studies that have shown how infrastructures influence and are influenced by practice, ongoing valuation highlights that infrastructuring should also consider how infrastructure projects produce and relate agencies of assessment in different practices (Cecez-Kecmanovic et al. 2014). The success of an infrastructure is assessed differently in different practices, and infrastructuring, our findings indicate, must contingently relate these agencies of assessment. In infrastructuring, agencies of assessment will influence and be influenced by the infrastructure project. In this context, relating involves the inclusion of actors positioned to determine success or failure in a more informed and grounded manner than a predefined value-realisation plan can do. The repair literature has indicated that focusing on processes of valuation will highlight how and whose values are materialised in different infrastructuring practices (Suchman 1987; Houston et al. 2016). Adding to infrastructure studies that have shown how infrastructure supports productive collaborative practices over time (Bossen and Markussen 2010), the concept of repair sheds light on the need for infrastructuring mechanisms to support collaborative (e)valuation over time.

Repairing the process by implementing a more punctuated and iterative implementation process involved creating activities in which the different practices of managers, vendors, and the healthcare practices met. These episodes included collaborative repair work with material artefacts that we found to be important for the participation of care practitioners, enabling them to grasp the extent of the infrastructure and influence the formation of it. We found examples of this form of repair in the collaborative alarm routing (see Figure 3) and positioning of sensors (see Figure 4). Technology vendors provided material artefacts in the form of software tools, which allowed practitioners to adapt the technology to their particular needs. Our findings suggest the necessity of materialising the future and envisioned infrastructure in order to make practitioners in infrastructuring capable of balancing their current needs with those of the future (Ribes and Finholt 2009). Our findings lend support to studies of participation in infrastructuring (Karasti 2014; Bødker et al. 2017), because we find that infrastructuring differs from traditional design projects as a result of its entanglement with new and existing packaged solutions, governmental standards and regulations, diverse collaborating organisations, and various user groups and practices. Consequently, infrastructuring does not necessarily immediately lend itself to the iterative-design ideal. This makes design with 'minimum viable products', which is the preferred bottom-up method for agile and lean development in the innovation literature, problematic. The reason for this, as Hanseth and Lyytinen (2010) explain, is that bottom-up approaches in infrastructuring are not isolated activities, but must effectively relate to how the existing infrastructure (with various systems and practices) adapts technically and socially. Karasti et al. (2010) use the notion of 'continuing design' to broaden the bottom-up/in-use perspective in an effort to explain that the boundaries between different sequences of technology projects, such as use, design, implementation, modification, maintenance, and redesign, are blurred in infrastructuring.

Since isolated design is problematic in infrastructuring, the literature on participatory infrastructuring has specifically considered the role of material artefacts, or 'things', in participatory infrastructuring (Karasti 2014). We find that material artefacts occasioned discussions of important issues, such as how the alarm routing would fit with current work practices, and importantly, that they helped to shape the operations of the system, such as the positioning and identification of location sensors and smart doors. The artefacts also triggered discussions that connected existing work processes with the future technology-supported work processes (supplemented with experiences from other sites). Participatory infrastructuring with material artefacts can be considered as changing the problem (i.e., the emerging technology-supported practice) through a collaborative selection and specification of features and functionality in the infrastructure (Karasti and Baker 2004). This is in line with Karasti´s (2014) review of PD literature, some of which consider 'things' a key mechanism in participatory infrastructuring in order to draw together various technical objects and recover democratic design processes in heterogeneous infrastructuring contexts.

A distinctive trait of the material artefacts here is that they do not represent the infrastructure per se. Rather, they signify something emerging. Ehn (2008) maintains that infrastructuring should design solutions that are open to future configuration. We find that the material artefacts in this case were used to make choices and to define and tailor the infrastructure. They functioned as a means of shaping the future technology-supported work practice. Future adaptations to the technology were indeed possible, but such adaptations would fall outside the budget of the implementation project, and the costs for later adaptations would have to be covered by the individual health and welfare centres as opposed to the infrastructuring project. Working with the material artefacts during the implementation project was therefore important in order to tailor the system as much as possible during the implementation phases. The material artefacts as used here are stand-ins that never truly catch up with the infrastructure (Knorr Cetina 2001). Still, by being as specific as possible, they spur interest in the infrastructure to come, not necessarily because care practitioners gain a particular interest in the technology, but because the artefacts indicate how their work will be influenced. The material artefacts, more than providing answers, make tensions visible so that repair can begin (Neumann and Star 1996). Materials allow for the investigation of how working with the new infrastructure versus the existing will play out, and they enable concrete discussions of how practices differ across various health and welfare centres. Instead of aiming for unity and similarity, a key role of materials is to bring inherent differences to light. Although differing from Ehn (2008) on the practical possibilities of openness of infrastructuring in practice, our findings support the perception that 'the real challenge is to design where no consensus seems to be within immediate reach' (ibid., p. 100). It falls to infrastructuring to create networks, processes, activities, and materials in which such small-scale operations can be performed in order to identify and work out tensions between large-scale practices, interests, and technology (Parmiggiani et al. 2015).

6 Concluding Remarks

In this study, we have investigated how infrastructuring can progress in the midst of ambiguity. Our analysis builds on infrastructure research that has shown that experimental development (Hanseth et al. 1996; Parmiggiani et al. 2015), flexible architectures and modularised systems (Grisot et al. 2014), and harmonising short-term and long-term concerns (Karasti et al. 2010) are central to infrastructuring. Taking an ecological approach to infrastructuring, we have shown how several facets of change are included in infrastructuring. The combination of facets leads to ambiguity, which infrastructuring must address.

This study contributes to the literature on infrastructuring by addressing the ways sociotechnical infrastructure repair relates to the repair of the infrastructure project itself. In our case study, repair included the creation of value-networks that blurred the borders between the vendors and the municipality and between municipal management and care practice. New roles were created and relationships changed. What emerged was a finer-grained process within the high-level, governmentally standardised framework, in which negotiation between technologies, practices, and experiences produced more attuned evaluation criteria and valuation networks. Finally, material artefacts, although they fell short of representing the infrastructure, related current practice to the future infrastructure by raising questions, spurring reflections, and encouraging care with regard to the progression and emerging shape of the infrastructure. Taken together, the value-network, process, and participation via material artefacts constitute infrastructuring as ambiguous repair.

In sum, our findings are in line with Jackson (2014), who explains that different forms of breakdown are not only inevitable but have generative implications. Complementing accounts in which 'heroic' local actors are able, in the face of attempts to change or standardise their work practice, to rework implemented systems in their favour (Williams and Pollock 2012), the repair perspective suggests that infrastructuring must detect and deal with tensions as a source of generativity and innovation during the purchasing, adaptation, and implementation phases of infrastructure projects. Repair focuses on the smaller, mundane episodes of breakdown and repair that occur in infrastructuring. It highlights as important drivers of infrastructuring the marginal and mundane tensions and the emerging collaborations required to work them out. Considered in this way, the generative potential of repair has implications for both research and practice.

In terms of research, repair reminds us to detect how, where, and when relations change (Ribes et al. 2013). Because roles are indeed mutating, it becomes a matter of looking at the borders of the value networks, the processes, and the artefacts used to enable participation in order to see who and what is inside and what is left outside infrastructuring (Bowker and Star 1999). Who should be included, and what are the reasons for their exclusion? In what way is the project breaking, and is it generative? Why or why not? We suggest that mundane breakdowns in infrastructure projects can uncover relevant aspects of the actual decision, implementation, and valuation processes involved in digitalisation and change. If we do not trace out these processes, we may let factors that underpin infrastructuring be 'relegated to the background, or ignored entirely' (Williams and Pollock 2012, p. 9). This is in line with Bødker et al. (2017) who argue for a consideration of how project participants are not only engaged in designing technology, but also in creating structures, networks and agreements. Further case studies in health, care, and other contexts can explore, refine, and extend the repair mechanisms of infrastructuring. We believe that such an understanding potentially can strengthen the influence of research on the design, implementation, and evaluation of infrastructure projects. By relating sociotechnical concerns with the more general organisation of the infrastructure project—e.g., by highlighting the resources, work, and care required by users at implementation sites—studies can provide insights which can inform decision-making processes in infrastructure projects. These are processes that are important for the emergent shape of the infrastructure.

Considering infrastructuring as ambiguous repair also has practical implications. By questioning the application of traditional design and project methods in infrastructure implementation processes, it can inform the relevant levels of an organisation, from practice to management, of the importance of a special kind of care for the infrastructure project. Jackson (2014) calls this an ethics of mutual care and responsibility for how the technology we rely on comes about. In particular, mundane episodes of breakdown and repair highlight how and whose values are materialised in the infrastructure practice (Houston et al. 2016). Making this engaged perspective applicable requires an ongoing effort among researchers to translate the language and insights of research into practical tools and methods for practitioners of infrastructuring. An understanding of infrastructure projects as ongoing processes of breakdown and repair can help projects detect values above and beyond predetermined return-on-investment specifications and outdated requirement specifications. The contingent and generative characteristics of repair also signify the possibility for different choices to be made when projects are underway.

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