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THE SNOW, THE DIRT AND THE SMARTPHONE

Exploring Mobile Technology Use By Blue-Collar Mobile Workers

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ABSTRACT

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The utilization of mobile phones has led to higher levels of accountability among blue-collar mobile field workers, who mostly rely on the physical performance of their work. Nowadays, maintenance and construction employees are responsible to report information about their work practices and outcomes through mobile technology in the field to greater extents than when reporting was done by filling paper forms. Such data serves the back office to administrate movement of resources such as trucks and supplies required in the work tasks and to monitor manual labour carried out in dispersed locations or when isolated in the field.

Mobile workers face various limitations and mental workloads arising from their distinctive technical work conditions and due to their spatial mobility, which affect their ability to interact with devices and to comply with workplace demands. Further, the complexity of their work tasks often increases due to no readily available information technology solutions. As a result, mobile workers often experience uncertainty and ambiguity when reporting and processing information, which can subsequently hinder work in the field instead of supporting it.

The main aim of this study is to learn how different contextual limitations and usability issues affect the practices of utilizing mobile phones for the purpose of reporting data in the field. Focus is put on the study context of *M-Reporting,* a mobile application through which the thesis explores the practices of reporting task-related data by maintainers, drivers and construction workers.

A field study guided by the contextual inquiry data-collection technique was conducted amongst 12 participants carrying out their real tasks and interacting with ICTs across nine work sites. The field study enabled collecting rich qualitative data which was interpreted and analyzed. The findings were analyzed by using theoretical analysis frameworks on mobility. To assess the usability of M-Reporting, Hertzum's method of usability analysis was applied.

The findings reveal that workers face different contextual limitations that negatively affect their ability to report from the field. As a result, workers were found to improvise by delaying data entry, by favoring available alternatives to report and by prioritizing their other work tasks when there was no compelling need to report immediately. In addition, workers were found to develop particular reporting habits due to situational and organizational usability issues.

In order to better adopt the process of reporting by blue-collar mobile workers within the field, future process improvement considerations were drawn and presented to the service provider and to the blue-collar mobile workplace.

Key words and terms: Mobile technologies, human-technology interaction, remote and mobile work, human factors, mobility, contextual inquiry

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1. Introduction

The increase in the capabilities of mobile phones has brought many new functionalities and possibilities for their utilization. The mobile phone has been transformed from a mere communication device to a multimedia platform capable to support a variety of other services. In the professional and commercial spheres, mobile phones are utilized in different fields of work, serving numerous types of employees for various work-related purposes, in fixed and mobile settings.

In light of its recently developed functionalities, small size and high portability, the mobile phone has also brought to serve the so-called blue-collar employees who perform heavy duty work, out in rustic and mobile work environments. Furthermore, mobile workers in modern countries rely on their mobile phones not only to communicate, but also to collaborate and create content and upload it to their fellow workers and supervisors. In many blue-collar mobile work surroundings, it is now a common practice to report information such as task fulfilments or working hours and to send invoices while being on-site.

In a macro view, the mobile phone virtually diminishes the use of paperwork, minimizes administrative hours and contributes to the optimization of enterprises. In a micro view, the mobile phone helps to lower levels of uncertainty generated by geographic work settings by providing remote access to resources that otherwise are available to desk workers only (Perry et al., 2001). Mobile solutions can potentially promote a collaborative environment, contribute to troubleshooting and problem-solving processes and support social connections between isolated team members. Further, the diffusion of data-based mobile solutions fosters a sense of community amongst dispersed workers. (Bakewell et al., 2018)

At the same time, much of the recent literature on remote and mobile work has pointed out that the well-being of workers is negatively affected by decreasing their control over their jobs. This is due to a growing demand to utilize new technologies. The utilization of modern technology causes concerns over the lack of privacy and invasiveness of monitoring technologies. (Bakewell et al., 2018; Tarafdar, 2018; Vartiainen and Hyrkkänen, 2010)

Mobile workers can in some context have low social, psychological and physical well-being due to the changing work requirements and mental workload caused by multi-locational work (Vartiainen and Hyrkkänen, 2010). Mobile workers carrying out labor in the outdoors differ from office workers and are exposed to different situational factors such as extreme weather conditions and technical limitations stemming from their mobility and varying work surroundings. Blue-collar mobile workers are constantly on their feet or inside trucks moving between places and using their hands to operate tools

and machines. Such technical limitations potentially disable the ability to hold mobile devices and impede handheld interactions.

Furthermore, the utilization of the mobile phone in blue-collar workplaces has led to higher levels of accountability among workers. Mobile workers who carry out manual labor are responsible to share and document their work practices through mobile technology to greater extents than ever before. (Kristiansen et al., 2018) Poor understanding of the real requirements of workers as technology users and the complexity of their used systems can potentially hinder manual work carried out in the field rather than supporting it (Mitchell et al., 2006).

Moreover, information processing tasks are often experienced with uncertainty and equivocality due to the lack of data or due to the ambiguousness of information required to execute tasks (Tarafdar, 2018). The demand to process and report information is usually met by workers exercising an autonomy when utilizing their mobile technologies, given they have enough control over their use. Their level of control is subsequently determined by the readiness of their daily used mobile solutions and the conditions of the physical spaces allocated to workers inside the workplace. (Tarafdar, 2018).

In this study, the focus was put on the study context of one organization where workers utilize the M-Reporting system, a mobile reporting application. Workers in the study context are accountable to report information about their tasks in a day-to-day manner. A contextual inquiry amongst three workforces; maintainers, drivers and construction workers was conducted with the focus on collecting data about the reporting process as it was carried out within each context. The investigation opened up a window to better understand the characteristics of their work tasks and the environments where human-technology interaction for the reporting process is carried out in different roles.

The field study relied on the conduct of contextual interviews amongst 12 participants, real mobile workers and their foremen while they were carrying out real work activities. The field study was conducted across nine sites in one municipality during the winter months. The exploration in the field offered an opportunity to observe and interview workers carrying out activities such as city street maintenance, snow-removal and road maintenance, construction driving errands, construction of infrastructures, spatial data and measurements, supervision and administrative work, all while interacting with tools and technologies for various purposes.

The first aim of this thesis is to explore the conditions and the characteristics of each work context under which workers utilize their mobile phones to keep up with workplace demands to report information about their tasks. To understand the circumstances I explore how physical and virtual space are utilized by workers in their workplace.

The second aim of this thesis is to identify the limitations and the usability issues that mobile workers face when utilizing their devices for reporting purposes in the field. In order to do so I will first set out to draw the demands to report, and second, set out to learn what kind of reporting practices are carried out by workers within the field.

Early in my visits to the field I discovered that the M-Reporting system was not visibly used by workers within the field and as a result explaining why it was so became a part of my mission. Since opportunities to observe workers carrying out their reporting tasks from the field were scarce, I turn to explore the general use of mobile technologies by workers.

This invites more opportunities to observe how interactions with ICTs are affected by different factors. By looking at physical, social and interactional characteristics of work it would be possible to understand how such factors shape workers' requirements for reporting process in each of the contexts. Furthermore, it would be possible to comprehend how interactions with tools and data could be manifested by the use of ICTs. This could subsequently bring insight about more effective services in mobile work.

In addition, the exploration in the field also looks to understand how usability issues in the process of reporting can affect ICT use practices across the explored work contexts. Doing so might lead towards a better understanding of user needs in the process of reporting from different perspectives of usability.

The third and final aim is to learn whether the conduct of a contextual inquiry can subsequently contribute to future recommendations to the process of reporting. Even the slightest improvements in the interface or process could potentially yield a quicker way of reporting that can save hours of work, improve user experience and cut the running costs of organizations.

Wrapping up the research aims listed in the previous paragraphs, the study aims at answering the following three research questions:

Q1. What are the unique circumstances under which the use of mobile phones for the purpose of reporting by blue-collar mobile workers occurs?

Q2. To what extent do possible limitations affect the use of mobile phones by blue-collar mobile workers for purposes such as reporting in remote and mobile environments?

Q3. Can the conduct of a contextual inquiry suggest new ways to cope with such limitations?

This thesis contains five chapters. Chapter 2 provides the background necessary to understand mobile work contexts, the theoretical analysis framework used to analyze the findings and the methodological approaches used in field research. Chapter 3 first provides an overview of the M-Reporting application and the mobile work cases explored in this study. Further, it describes the participants and their equipment, then describes the materials used in the field research, and finally describes the procedure of the field study and the data collected. Chapter 4 presents the findings from the field study. Chapter 5 discusses the findings and provides suggestions for future utilization of mobile technology in mobile work. Chapter 6 concludes the thesis.

2. Literature review

There is a need to further clarify the concept of mobile work, especially when engaging in learning human-technology interaction in contexts of physical mobile labor carried out in multiple locations. Moreover, there is a need to describe how methodological approaches are utilized to explore human behavior in such work circumstances.

In Section 2.1 I introduce the characteristics and the implications of mobile work. In Section 2.2 I discuss the role of technology and the importance of mobile technology and usability in data-driven mobile workplaces. In Section 2.3 I introduce the conceptual framework used to explore and analyze the characteristics of use of mobile technology in mobile work during this study. In Section 2.4 I present the theoretical background behind field research to introduce the methodology that was necessary in my field study.

2.1 Mobile work

Mobile workers, *dispersed* or *multi-locational workers* are defined as workers who "*spend some paid working time away from their home and away from their main place of work*" (Gareis et al., 2005, p. 54). The work they carry out can be done during business trips, in the field, by travelling or directly from customer's own premises. By definition, mobile work is labor that is being carried out at least once per month away at a changing mobile location. Workers who carry out at least 10 hours of work per week outside of the main office for such purposes are defined as *high-intensity mobile workers*. (Gareis et al., 2005)

In the beginning of this millennium, 28% of the total employees in the European Union were engaged in mobile work to some extent. Approximately half of them (15%) were high-intensity mobile workers. In Finland, the figures were much higher. Approximately 44.5% of the total share of workers were considered mobile workers, and close to 20% of them engaged in high-intensity mobile work. (Gareis et al., 2005)

As far as the frequency of work carried out at mobile locations is concerned, many mobile workers in the European Union were found to spend significant shares of their working hours away from their home or the workplace. 15% of all mobile workers spent 2 hours or less per week being "on the move", 18% spent 3 to 6 hours, 29% spent between 7 to 16 hours, and 38% spent at least 17 hours per week away from their home or the workplace. (Gareis et al., 2005)

Furthermore, it is common to distinguish between two groups of mobile workforces; mobile knowledge workers and mobile field workers. The mobile knowledge workforce includes personnel in sales, journalism, real estate, tourism, healthcare, social work, etc. The mobile field workforce includes personnel in fields such as, transportation and delivery, emergency, security, maintenance, construction, electrical, repair and installation engineering, or in any field where there are workers who are required to be

on the move in order to get physical work assignments done. (Kurland and Bailey, 1999; Yuan and Zheng, 2009)

What makes mobile work mobile?

Both the concepts of '*mobile'* and '*mobile work'* can be quite ambiguous from organizational and employment perspectives. The terms '*mobile'* and *'mobility'* suggest that mobile work holds a high degree of relevance to wireless technologies. In most cases of mobile work, there is the possibility that workers will move and perform tasks from anywhere, at anytime, supported by mobile technologies in very flexible ways and in very flexible work situations. (Vartiainen, 2006)

Being mobile, in the case of work, is defined as "*a quality of an individual who moves to and from different places and works in them and, while travelling, uses information and communication technologies as tools*" (Vartiainen, 2006: 14). Mobile work, similarly to other labor, is a goal-oriented activity that reveals more contextual complexities (Vartiainen, 2006).

2.1.1 The development of mobile work concepts

The emergence of mobile forms of work was greatly related to the growing interest in telecommuting during the 1970s in the United States. Outsourcing and telecommuting were ways to cut costs involved in having people to commute to and back from work by allowing them to work from home or by allocating a space for work close to their homes. In the 1980s, telecommuting was catalyzed by concerns about heavy traffic and associated pollution in highly populated areas. In addition, it was a way to reduce costs of running an office space. (Kurland and Bailey, 1999)

At the beginning of the trend, there were several traditional forms of remote work, such as home-based and satellite office work and work held at neighborhood centers. Very soon, the advancement in computer-based solutions led to the creation of alternative forms of remote work that were extended outside of home-based telecommuting and outsourced work. Other forms such as *hot-desking, hoteling, collaborative offices* and *day extenders* have then emerged. All these together constitute what is known as the generic term of *telework*. The term *teleworkers* is now commonly used when referring to workers who spend large shares of their time doing work from home. (Kurland and Bailey, 1999; Vartiainen and Hyrkkänen, 2010)

As opposed to the United States, in continental Europe, the term *eWork* is more frequently used. The concept of eWork is used to indicate high-intensity mobile work that takes place by using an online connection to the internet and/or to the company computer systems. eWork fundamentally pertains to the traditional form of home-based telework employment of individuals but extends to include shared work that is being held in call-centers or other remote back-offices. eWork is also used to cover *tele-collaboration work*, a telemediated form of work where people collaborate in virtual teams across the

boundaries of one single organization. (Gareis et al., 2005; Vartiainen and Hyrkkänen, 2010)

Finally, the emergence of *mobile work* was made possible thanks to the increase in the capabilities of mobile technologies. The utilization of mobile tools in multi-locational work has increased the possibilities to work from multiple places at a time. Work and collaboration could be carried out in a fixed location or on the move between public spaces such as airports, hotels and cafés, or open spaces such as roads and fields. (Vartiainen and Hyrkkänen, 2010)

To summarize, the development of mobile work concepts was directly related to the advancement in mobile technologies. The traditional telework was work that was primarily carried out from remote-but-fixed places outside the main office, supported by first generation computers. eWork was developed as soon as flexible use of time and place was mediated by the development of *information and communication technologies (ICTs)*. Therefore, the sense of communication with employers was enhanced. Mobile work has emerged due to a significantly more flexible use of time and space by the support of portable ICTs for working and collaborating from diverse locations. (Vartiainen and Hyrkkänen, 2010)

2.1.2 Implications of mobile work

Mobile work has very distinctive implications that stand in opposition to other fixed and remote work. Foremost, other forms of work are bringing workers into offices and homes, whereas in mobile work they are sent to work away at multiple locations. (Kurland and Bailey, 1999)

Secondly, in white-collar work individuals essentially carry out tasks from one fixed location and collaborate with others by the assistance of electronic communication and computers from office like environments. In contrast, mobile workers are laborers who spend significant shares of their workhours away from a centralized workplace. They often work by using ICTs from home, and more so, from a car, a train, or any other designated location required as part of their work requirements. Mobile workers are therefore in constant need to be acquainted with working from a variety of locations, unlike other workers. (Kurland and Bailey, 1999; Vartiainen and Hyrkkänen, 2010)

Furthermore, most mobile workers have only few hours per week face-to-face contact with their managers and peers. In mobile work, workers are being asked by the employer to head out to the field for long periods of time, while they are being linked to the workplace merely with the help of their mobile phones and the internet. (Kurland and Bailey, 1999)

According to Kurland and Bailey (1999), the implications that are associated with mobile work can be divided into three levels, organizational, individual and societal. Each level has both challenges and benefits:

- *Organizational challenges* refer to the lack of monitoring and measurement of performance, absence of informal interactions, work coordination, communication and schedule maintenance issues, and technology issues. *Organizational benefits* can be related to greater productivity and lower rates of absence from work.
- *Individual challenges* are related to factors such as social and professional isolation, uncertainty, longer hours, lack of access to resources and levels of technical proficiencies. *Individual benefits* can be a higher sense of autonomy, a more flexible schedule and the absence of office politics.
- *Societal challenges* can appear as a result of degradation in levels of interaction with other people such as colleagues and supervisors in a way that can affect society in the long term. *Societal benefits* are more opportunities to interact with people outside of the organization in some forms of mobile work. Use of technology in mobile work is considered to foster a sense of community. Mobile technology can facilitate collaborative ways to solve problems at work and contribute to higher sense of social cohesiveness among dispersed mobile workers. (Bakewell et al., 2018; Kurland and Bailey, 199)

In addition, mobile workers may face a decline in levels of morale or even frustration if required to spend more time travelling than seeing people face-to-face (Crawford et al., 2011).

2.1.3 Blue-collar mobile workers

This thesis will focus on work in physical mobile field work contexts, rather than on mobile knowledge workers. Therefore, this section provides a brief introduction that aims at articulating the kinds of contexts of blue-collar mobile work that are expected during such exploration.

According to Gibson and Papa (2000: 68) the term *blue-collar work* refers to "*skilled tradespeople, factory workers, farmers and other laborers*". It is common to distinguish between blue-collar work and *white-collar work*, where managerial and professional labor is typically performed in office environments and *pink-collar* work, which refers to secretarial and service related types of labor. Blue-collar work generally implies labor where individuals are involved in some type of physical and manual duties that are compensated at an hourly wage, rather than a fixed one. Blue-collar mobile workers rely on the physical performance of their work.

In my literature review, I found no statistics to help gather the number of blue-collar mobile workers cohorts compared to their parallels in white-collar professions. However, when trying to analyze different factors to determine the probability of workers practicing

mobile work, professional laborers are much more likely to take part in it (Gareis et al., 2005).

Nevertheless, examples for mobile or fixed location blue-collar employment can be found in many occupations, such as assembly, manufacturing, processing, packing, oil field work, waste disposal and recycling, construction, warehousing, technical installation and more. Blue-collar work often involves labor where people are required to physically build or maintain something and can refer to workers performing both static and mobile work. (Gibson and Papa, 2000)

One of the few articles addressing blue-collar mobile work context was by Luff and Heath (1998), which explored the issue through three case studies. The first case study focused on the practices and the need of awareness and communication of workers in the hubs of the London Underground found that workers needed to keep track of huge quantities of information that was flowing into their operational rooms. It was also found that as result of situational circumstances, the workers were required to be mobile and away from the operational rooms. Workers then lost their access to information and knowledge of what happened on train platforms, as they were cut out from important conversations between peers.

The second case study was conducted in a construction site found that replacement of a paper sheet that was used to record how much time was spent on task by an electronic notebook actually hindered work. It was discovered that the paper sheets were more mobile than the notebook, which made the process of filling variables a more complex procedure. (Luff and Heath, 1998)

The third case study was conducted to learn about the collaboration of workers in hospitals and found that the medical record sheets of patients are important resources for the communication and collaboration of medical workers. (Luff and Heath, 1998)

Brodie and Perry (2001) conducted a research to study mobile phone use by blue-collar workers, such as electricians, hairdressers, builders and cleaners. They found that for the most part, workers could not perform their work as they should without their mobile phones. Mobile phones were found to be essential to the capture and communication of important information coming from other stakeholders. Mobile phones were also found to have a social role in communicating with the outside social environments of workers and with their apprentices.

Tarafdar (2018) suggested that the use of ICTs by blue-collar and remote workers imposes many risks on workers. For instance, negative effects such as “spillovers” between work related activities and non-work-related activities emerge. Workers often use their mobile phones to have their private conversations, which subsequently leads to conflicts between their work and social lives and to information and work overloads. Furthermore, use of ICTs in mobile and remote work could lead to dangerous situations as result of multi-tasking between mobile phone interactions and driving. Interactions with ICTs to access data can be susceptible to fatal situations due to mistakes that may

put human security at risk. For example, in work that involves utilizing heavy machines in construction sites, workers can be at risk due to fatal misunderstandings.

Finally, Orr (1986) conducted a field study amongst photocopier repair technicians. The study emphasized the importance of narratives in understanding how technicians overcome problems in the diagnostics of broken copier machines with the use of anecdotes.

2.2 Technology at the workplace

As previously pointed out, mobile work differs from other forms of work (such as, normal office work) and remote work (such as, telework and eWork). Different spatial, temporal and contextual mobility factors impose a complex variety of limitations on mobile work.

When people work in the office they have a higher sense of familiarity and certainty with their close and fixed environment, and with the equipment available within it. Everything around the office is fixed and tailored to their needs and whatever information they may require is available at any time. When there are breakdowns in technology, problems are usually easily fixed within a short time. The office structure itself provides a higher sense of familiarity and allows a higher sense of freedom to organize work. (Perry et al., 2001)

In contrast to office workers, mobile workers are not entitled to the same richness in resources, the same organized locations and immediate access to information. Workers who need to move long distances and encounter new remote work settings are exposed to higher numbers of unfamiliar work contexts. This leads to higher levels of uncertainty at the workplace. Some of these contexts are likely to be more unfamiliar to workers in terms of the availability of technology, the whereabouts of communication tools, vacant workspaces and noise factors. Moreover, the lack of contact with other workers, peers and superiors affects the amount of interactions. It reduces the ability to be exposed to new information or to seek support. (Perry et al., 2001)

Furthermore, mobile work challenges the organization itself since it requires to deploy systems and tools to monitor the progress and the outcome of workers in various work contexts.

2.2.1 Accountability in data-driven workplaces

Nowadays, an increasing number of organizations rely on information generated by their employees. Different means of technology were diffused into manual labor workplaces and are utilized by blue-collar workers. More so, the use of ICTs is often required to accomplish blue-collar work tasks. As result, workers are required to use technology to share and document as part of their workday routines by reporting, uploading or accessing information. (Kristiansen et al., 2018; Tarafdar, 2018)

This creates a sense of *accountability* at the workplace; on one hand, organizations track and monitor work progress, and on the other hand, workers generate data that relates

to the practices, progress and outcomes of their work. Moreover, workers are increasingly required to hold some computing skills to be able to comply with their work responsibilities. (Kristiansen et al., 2018)

Job demand and job control

Work in data-driven workplaces means higher worker demands to process and generate information. In mobile work, workers face sets of rather unique work conditions. Their accountability to generate and process information can be seen through the relationship between *demand* and *control.* Essentially, workers are required to have control over information processes to counter such demands. Workplace demands are usually manifested in two different ways; first, in *uncertainty*, which occurs due to lack of information that is required to accomplish work-related tasks. Second, by *equivocality,* which occurs due to challenges in interpreting information that is required to accomplish work-related tasks. (Tarafdar, 2018)

Workplace control over use of ICTs is usually manifested by *autonomy*, which means that workers can have high control over how they generate and process data in the workplace. The relative high level of control often results in workers improvising due to lack of adequate spaces for such tasks. In blue-collar mobile work it often means that workers could develop somewhat unconventional ICT use practices. (Tarafdar, 2018)

2.2.2 Enterprise software

Enterprise systems are large software system platforms that aim to integrate all the information flowing through the organization and to contribute to its effectiveness and competitiveness. There are different types of enterprise software categorized based on their different functions in relation to the business operation. (Smolander et al., 2016) For instance, enterprise software systems are used to manage supply chains, knowledge and data, business intelligence, customer relationships, resource planning and other functions.

The most relevant type of enterprise software to this present thesis is *enterprise resource planning* (ERP) system that aims at managing the internal processes and the information that flows across the enterprise. ERP systems have known to contribute to the improvement of operational efficiency but criticized to be relatively complicated to use and learn. (Singh and Wesson, 2009)

The complexity of ERPs has been suggested to be mostly due to the large scale of data that they process and integrate. This has culminated in system user interfaces that are prone to have many usability issues. Such usability issues can potentially impede the degree to which users can use systems to accomplish their work-related tasks. (Singh and Wesson, 2009) More so, poor usability holds a negative outcome on the productivity of users and affect the likelihood of systems to be adopted by its users (Babaian et al., 2014). Viewpoints of usability are discussed further in Subsection 2.2.4.

2.2.3 Mobile technology and access anytime, anywhere

In data-driven workplaces mobile technologies are a way to reduce the effects of these existing difficulties that mobile workers face, thus by bridging the gap between workers' remote locations and their required resources. Mobile devices, applications installed on them and the abundance of mobile services are the main drive of mobile work. Mobile technology as a work tool allows workers to communicate and collaborate when required very flexibly and therefore, creates more opportunities to work remotely or on the go. (Vartiainen, 2006)

Mobile technologies support access to the same resources and information available to office workers, wherever and whenever mobile workers are away. The use of mobile technologies is proposed to allow mobile workers to regain control and to eliminate levels of uncertainty, and the limitations and complexities imposed by mobile work environments. (Perry et al., 2001)

The notion of access anytime and anywhere hypothetically enables workers the freedom to participate in interactions, and as consequence, to be more place-independent (Mitchell et al., 2006).

Criticism of access anytime, anywhere

The notion of access anytime and anywhere has been questioned by some who regard technology to be of second importance in the efforts to support mobile workers at their work. It is claimed that the idea of access anytime, anywhere does not adequately reflect the reality of interactions with mobile technology in the genuine settings of mobile work. (Mitchell et al., 2006; Rossitto, 2009)

Instead of focusing on technology, it is opted that the focus should be put on the nature of work that is supported and on users who are actively participating in specific activities while they use technology. Different tasks might need different levels of access to information and might only be performed on specific times. (Mitchell et al., 2006; Rossitto, 2009) Furthermore, it is argued that the use of technology in mobile work could not be detached from its physical location (Rossitto, 2009).

Understanding mobile work contexts the wrong way could yield technological solutions that can be sometimes used in a wrong manner, and can subsequently hinder mobile work instead of supporting it due to usability issues (Perry et al., 2001).

2.2.4 Aspects of usability

Usability is a concept that transcends over many perspectives. Its true meaning and definition are largely still debatable and are continuously explored by many. (Hertzum, 2010) In layman's terms. good usability should guarantee that people can do what they need to do while using the system.

The ISO standard provides one prominent interpretation to the concept. According to the ISO standard usability is the "*extent to which a product can be used by specified users*

to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use". Under such definition, usability can be seen as a combination of three different concepts, *effectiveness*, which is regarded as the level of accuracy of which users can accomplish their goals. *Efficiency*, which is regarded as a comparison between the effectiveness and how resources were used to achieve user goals. Lastly, *satisfaction*, which is regarded as the assembly of attitudes towards the use of a product. (ISO 9241-11: 2010)

In this study I will introduce Hertzum's (2010) approach towards usability. Hertzum proposes a method that provides different ways to view usability as a set of six images, or viewpoints. Each usability image provides opportunities to emphasize different aspects. (Hertzum, 2010)

- *Universal usability* suggests that usability should focus on the challenge of having systems that are suitable for everyone to be used. In order to obtain universal usability the system should concentrate on human variation, such as their age, background, gender, disabilities, values, use habits and so on.
- *Situational usability* suggests that usability should consider the situatedness of interactions and the ability to use the system in a wider context of given situations with other users and tasks.
- *Perceived usability* suggests that usability should focus on the subjective experience of using a system. It is usually user centered and comes as a result of internalizing the organizational conventions, the use situation and cultural aspects. Perceived usability is likely to determine whether or not a system will be successfully adopted, used or liked by its users.
- *Hedonic usability* suggests that usability should be focused on user's pleasure of using a system. Usability is the sum of joy and positive emotions rather than on whether or not a task was accomplished.
- *Organizational usability* suggests that usability should be focused on team work and how users collaborate within the organization. It strives to locate how structural and collaborative aspects combined with the human factor are affected by using the system. Organization usability focuses on three collaborative elements; *common ground*, which is the establishment of a mutual understanding of the organizational rules and norms. *Awareness,* which supports the promotion of collaboration through alertness to progress of other collaborators. *Coordination,* which supports the coordination of tasks between collaborators.
- *Cultural usability* suggests that systems should take in consideration differences between the backgrounds of people (Hertzum, 2010). The concept of culture implies that people who share the same nationality, language and religion tend to believe, think and react similarly (Callahan, 2005). Cultural

> differences are commonly described by Hofstede's model of cultural dimensions, which assumes cultures and nationalities to be homogenous (Hofstede et al., 2010). In addition, cultural usability is often seen through business culture and how it is expressed through the strategy of a particular company. It is believed that individuals from the same organization often share the same attitudes as a result of shared sets of organizational rules, norms and goals. (Callahan, 2005)

2.3 Theoretical analysis frameworks

Section 2.3 introduces the conceptual frameworks that were used to analyze the findings gathered from the field study. First, Subsection 2.3.1 introduces the notion of space and place in mobile and remote work. Second, Subsection 2.3.2 discusses the mobility dimensions in mobile and remote work.

2.3.1 Space and place

The research of mobile technology has been concerned with studying theoretical and methodological aspects that deal with physical environments, as well as with the role physical environments hold in shaping interactions between human beings and technology. The matter of spatiality is important not merely in research, but also in supporting the process of designing systems for particular contexts. (Ciolfi, 2015)

The notion of space and place is given more attention since the current trend in mobile and digital technology is pushing towards more pervasive designs that are physically less restricted. The idea of pervasiveness of physical spaces has evolved from the more traditional idea of stationary desktop computers into ubiquitous computing embedded in everyday objects such as portable devices. This notion has penetrated to workplaces as well. Design processes aiming at producing technological solutions that are distributed in physical locations are now guiding professionals to think about spaces in more abstract terms, as augmented places and enhanced from their original states. (Ciolfi, 2015)

Furthermore, as the concept of mobility earlier suggested, mobile work is not only restricted to physical limitations, as people can be equally affected by spatial, contextual and temporal dimensions of work. To overcome these disablers they often use mobile technologies. Being mobile means that people also collaborate "on the move", with peers and managers by utilizing information and communication technologies, and thus being virtually and socially mobile as well. (Kakihara and Sørensen, 2002)

Space and the implications of work in multiple locations

The idea of space and place indicates that subsequently, work is always being done in some space. This notion holds true in mobile and regular work alike. The concept of '*ba*' (ba means "place") is used by Vartiainen (2006) and Vartiainen and Hyrkkänen (2010) to demonstrate how different work spaces can be distinguished. It refers to "a shared context

in which knowledge is shared, created, and utilized by those of interact and communicate there" (Vartiainen 2006:15). Ba assembles the physical, temporal, social, virtual and cultural spaces together. It incorporates the physical space, of where work is being carried, the virtual space, where interaction between workers is held, and the social and mental spaces, where the shared experiences, ideas and beliefs of workers come together towards achieving a shared goal.

It is common to distinguish between four different space-related categories:

- *A physical space* refers to the physical workplace that mobile workers utilize for work. It can be for example, the home, the main office or any other workplace, means of transportation such as vehicles, planes, trains or ships, the customer's home or a company's premises, a public space such as café or a restaurant or any space in the outdoors. (Vartiainen and Hyrkkänen, 2010)
- *A virtual space* refers to the virtual workspace of the worker, comprised by different collaborative tools and other media means used by individuals, groups or the whole organization, within different physical workspaces. (Vartiainen and Hyrkkänen, 2010)

  The term '*virtuality*' defines the attributes of something that does not really exist but has the potential to exist in an 'almost like' manner. A contemporary interpretation for virtual is of something that is "*not the same in actual fact, but almost like, and is virtual like in virtual reality*" (Vartiainen, 2006:20). In organizational terms, it is common to refer to dispersed teams or individuals working apart but towards a shared goal by a collaboration achieved by ICT tools as 'virtual teams' (Vartiainen, 2006). In a virtual work space, the online organizational network, enabled by internet and devices, creates a platform where workers can communicate, collaborate and share relevant information. As already suggested, the impact of virtual spaces grows when team workers are dispersed in different locations and are required to communicate and collaborate with each other to achieve a joint goal. (Vartiainen, 2006)
- *A social space* refers to the social circle, where individuals inside and outside the physical locations cooperate. The social space is comprised from team members, managers, customers or any other individual taking part and takes place at each of their physical work spaces. (Vartiainen and Hyrkkänen, 2010)
- *A mental space* refers to the thoughts, beliefs, ideas and experiences that may affect the worker's interpretation of the other three spaces. The mental space is not limited to one individual, as it can be shared and formed together with others by face-to-face encounters. (Vartiainen and Hyrkkänen, 2010)

According to Vartiainen and Hyrkkänen (2010), in light of this space-related categorical analysis it is possible to conclude that when mobile workers move within an increasing number of physical places, the versatility of the spaces grows. In every

new physical location it is essential to get acquainted with a new mixture of physical, virtual, social and mental spaces. Given by the higher number of physical places that mobile workers are required to visit and utilize for their job, it is safe to assume that multi-locational mobile work increases the complexity of work. The physical, virtual, social and mental spaces are summarized in Table 1, adapted from Vartiainen (2006).

Physical spaces
Which are settings, arenas and environments at home, in the main workplace ('office'), moving places (e.g. cars, trains, planes, ships), other places (e.g. partners', clients' and suppliers' premises), and third places (e.g. hotels, cafes, congress venues)
Virtual spaces
Which are connections (e.g. Internet, intranet, extranet, wlan, broadband), devices (e.g. laptop, mobile devices), and applications and services (e.g. e-mails, calendars, access to databases) enabling communication and collaboration
Mental and social spaces
Which are the shared common experiences, ideas and ideals based on human interaction and collaboration

Table 1. Spaces at the workplace. Adapted from Vartiainen (2006:16).

2.3.2 Mobility

Understanding what kind of circumstances affect mobile work and the possibilities for interactions can be better achieved by exploring the concept of '*mobility'*, which is one of the most prominent features of this type of work. By exploring mobility it will be possible to characterize the relationship between a place and the activities that are taking place in it. (Brown and O'Hara, 2003; Rossitto, 2009)

Mobility is, by definition, the quality of being mobile. The meaning of the concept widely stretches towards anything that is not static and can be applied to human and non-humans alike, and even to objects, symbols and images. The concept of mobility is quite commonly used in the narrower contexts of contemporary business and organizations. For example, in the concepts of '*mobile technology*' and '*mobile work*' that are typically used in work related contexts, the term mobility implies about their dynamic forms. (Kakihara and Sørensen 2004)

The term mobility was used in a variety of ways in the existing literature. Mobility stands for different forms of movement within space and time, and therefore, was used to address many contexts of mobility in work from various point of views. (Brodie and Perry, 2001)

In this study I chose to introduce Kakihara and Sørensen's (2002; 2004) notion, which embraces the spatial, temporal and contextual elements of mobility. During this introduction, I will clarify other related concepts that will be used in later stages of this thesis.

Kakihara and Sørensen (2002; 2004) have argued that mobility of humans could be structured and distinguished by three interrelated dimensions that expand mobility into a rather complex concept. These dimensions (spatiality, temporality and contextuality) are

often thought of as disablers that should be overcome by technological means, or alternatively, can be thought of as levels that affect the capability to interact under different work circumstances.

Spatiality

Spatiality, which can also be referred to as *locational mobility*, pertains to the ability to wander, travel and visit, which are the most immediate facets of mobility in human life.

Locational mobility is concerned with the location and movement of actors within space. The spatiality in mobile work first implies about the type of physical movement that is taking place, the possibility of people to travel from one place to another and to their remoteness from a fixed location. There can be *long-distance travelling* mobility that extends to large distances and *local mobility*, of short distance walking between rooms, buildings and nearby sites. (Kakihara and Sørensen, 2002)

In the context of mobile work, "*where*" can be considered as the most elementary question that is being asked in the daily agenda, as the geographical position of workers and the location of their available resources are constantly being altered. Knowing to where movement is extended is a key feature, as workers are often on the move. The type of movement of mobile workers, its direction and frequency are dependent of the work, but nevertheless, versatile. (Kakihara and Sørensen, 2002)

An example for spatial mobility could be, for example, long distance travelling, but there could be other modalities of spatial mobility as well. There are few common types: *Wandering modality* is a local mobility where people are on the move around a building or offices, *travelling modality* is a local mobility made by travelling using a vehicle, and *visiting modality* where short activities in a limited amount of time are being carried out at places where people do not usually work. (Kakihara and Sørensen, 2002)

Spatiality subjected to contextual factors can increase the complexity of the assignments and the interactions. First, the number of places workers are required to visit could change because of the work requirements. Second, the frequency of the visitations could change as well. And third, the nature of the physical mobility of workers could change as part of the requirements. Physical mobility and contextual factors could determine when and if at all it will be possible to interact by using mobile technology. (Vartiainen, 2006)

Physical mobility subjected to temporal factors can also determine the quality and the manner of interaction between people within the organization. The number of places used for work, the distance from one location to another, and the frequency of which people interact can be altered because of complexities related to spatial mobility. (Vartiainen, 2006)

Spatiality may also refer to movement of resources, like objects, information and movement of space itself. *Movement of space* is a movement that is being enabled by computers and computer-mediated communication between people. The implication for

such movement is that physical distance can no longer be the most dominant aspect of the interactions. In virtual spaces, the segregation between 'here' and 'there' breaks down. (Kakihara and Sørensen, 2002)

The resources one uses in mobile work are diversified, changeable according to the job and hence, very mobile as well. The mobility of artifacts is referred to as *micro-mobility* and was studied to understand the way objects are moved around and manipulated according to work conventions and within the work environments. The mobility and other affordances of equipment and artifacts, such as vehicles, tools and paper documents play an important role in mobile working and could provide an important input towards understanding the possibilities to interact under mobile work circumstances. (Rossitto, 2009)

Temporality

Temporality, which can also refer to as *operational mobility*, is mobility in relation to time and the flexibility of the organizational operation and its activities. Temporality is concerned with aspects of *time*, in relation to synchronous or asynchronous degrees of work, and *temporariness,* in relate to the durations of work. Operational mobility asks "*when*" something is ought to happen and "*how long"* will this something take. It discusses how freedom from organizational limitations such as fixed schedule affects the actions that are being carried out. (Mitchell et al., 2006; Vartiainen, 2006)

Operational mobility deals with analyzing the different temporal factors that affect the grasp of time within the organization. It is common to associate temporality with factors such as prescribed working hours, social, cultural and organizational behavior, and the environment and seasonal changes. Temporality can also affect the possibilities to interact and collaborate with others. (Kakihara and Sørensen, 2002; Mitchell et al., 2006)

In order to learn how temporal order at work is achieved, Kakihara and Sørensen have investigated two main features related to temporality:

The first feature is the extended perspective of *structural order* vs. *interpretive order*. The process of perceiving time in organizations can be achieved by following a *clock time* or a *social time*. Clock time is an objective perspective of time within the workplace, which is comprised from structural parameters. Social time is a subjective perspective of time comprehended by workers, which is an interpretation of the structural parameters. Mobile technology leads to more frequent changes in structural order of events in the workplace, which subsequently influence the way the clock time is perceived by employees. (Kakihara and Sørensen, 2002)

The second feature investigated by Kakihara and Sørensen is the dichotomy between *monochronicity* and *polychronicity* perspectives of temporality. Monochronicity pertains to how carefully people within the organization are structuring their activities in relation to time. In monochronic organizational culture, people would usually reserve special time

slots for their tasks and do one thing at a time. Lateness or interruptions in the order of events are not easily tolerated. Polychronicity refers to how well people accept changes in activities. In polychronic organizational culture, people will be more likely to forgive delays in structural order and will more often engage in multi-tasking. (Kakihara and Sørensen, 2002)

Since new technologies and ICTs were widely introduced to social lives, it is seeming that polychronicity of human interaction has increased. It is therefore believed that polychronicity at work, rather than monochronicity, is increasing as well. With the increasing number of interactions with mobile devices, e-mails and other asynchronous applications, people are more likely to be able or be required to handle multiple tasks at a time. (Kakihara and Sørensen, 2002)

The manner of how work and interactions are affected by temporality can be clarified by pointing out the following concrete components: First, they affect how much time is spent in different locations. Second, they determine the need to move from time-to-time between different places. Third, they affect how many people are needed to work at the same time on a particular task. Finally, they affect how many workers are available for work at the same time or at the same moment in different time zones. (Vartiainen, 2006)

Contextuality

Contextuality, which is also referred to as *interactional mobility*, is of equal importance because it tells about the ways, the circumstances and with whom actions are performed. While the spatiality and temporality aspects of mobility ask *where* and *when* actions are carried out, interactional mobility asks *how* the actions are carried out. (Kakihara and Sørensen, 2002)

Contextuality is mobility in relation to the technological means that induce connectivity and collaboration during work. Mobile workers, similarly to people who work at set locations, interact with peers and supervisors by using mobile technologies. Contextuality is a set of circumstantial factors that alter the mode of interaction. (Kakihara and Sørensen, 2002)

There are two dimensions of *interaction modalities* that influence the contextuality of interactions: *unobtrusiveness* vs. *obtrusiveness* and *ephemerality* vs. *persistence*. The level of obtrusiveness of interaction is determined by how the obligation to react and interact is imposed on people. The ephemerality of interaction is determined by how fast interactions dissolve and whether or not they leave behind a trace that requires further action. The interaction modalities of various communication technologies can be characterized by using these two dimensions as a framework. ICTs essentially create more opportunities for interaction with others in different interaction modalities regardless of contextual factors. (Kakihara and Sørensen, 2002)

In the context of work, interactional mobility could affect other mobility dimensions as well. For instance, consider a construction worker who receives an incoming call from

a supervisor when working in a hazardous environment. For any interaction to be made, the worker will need to timely postpone it or spatially move somewhere else safe, away from where interaction was not made possible.

The mobility dimensions are summarized in Table 2.

Dimensions of mobility	***Aspects of interaction***	***Extended perspectives***
Spatiality	- Where	- Geographical movement of not just humans but tools, objects, symbols, images, voice, etc.
Temporality	- When	- Clock time vs. Social time - Monochronicity vs. Polychronicity
Contextuality	- In what way - In what circumstances - Towards which actors	Multi-modality of interaction - Unobtrusiveness vs. obtrusiveness - Ephemerality vs. persistence

Table 2. Mobility dimensions. Adapted from Kakihara and Sørensen (2002).

Finally, the physical, temporal and contextual dimensions are very closely related and in many cases dependent on one another. A change in one dimension could result in causing a change in another or all dimensions. As result, the complexity of performing tasks raises and so does planning them. (Vartiainen, 2006: 30)

Mobile technology has a major influence on spatial and temporal dimensions due to the fact that technological developments were pushed by the motivation to overcome distances and save time. In respect to spatial and temporal factors, mobile technology hypothetically operates as an enabler. However, contextual circumstances could potentially hinder its use or even make it entirely unusable due to varying situations. (Kakihara and Sørensen 2004)

2.4 Field research methods

Field research is a methodological approach that aims to observe human behavior under natural circumstances. The process of field research is different to research conducted in laboratorial settings. The data collected in field study, similar to what is done in social sciences research, is raw and most often collected from geographical and cultural contexts that are not familiar to the researcher. In contrast to other approaches, field research enables the person who collects the data to vigorously observe, participate in conversations, extract information and interpret the data that is being collected. (Reyes-García and Sunderlin, 2011)

The field data allows researchers to discover possible issues by gathering users' experiences. After a consolidation of the data, the outcome is a general view of the practices and experiences of the user under the context of the research. (Holtzblatt and Beyer, 2014)

2.4.1 Contextual design

The task of designing a service or a system in today's world requires a more intimate approach than before. There is a fair share of competition, and companies ought to produce not merely the most functioning products, but also the most compelling and innovative ones. The challenge of being innovative requires to find ways to learn about the real needs of those who will use new services, which subsequently means to involve them in the process. (Holtzblatt and Beyer, 1993)

When the aim is to design a tool for supporting people at work, the main concern is then to collect useful data about how people conduct work and later analyze it. However, finding out in enough detail how people work and how to support people at work can be difficult, especially when contexts are unfamiliar to researchers. (Holtzblatt and Beyer, 1993)

Contextual inquiry

The first step in contextual design includes gathering users' requirements for the creation of new services or products. Directly asking the participants for their expectations from the tools they use, or are about to use, is not sufficient. First, users might not know what they themselves want, second, they might not be aware of the capabilities of technology, and lastly, they might not be able to accurately express what they do and how they do it. Therefore, the process of gathering user's needs requires much more engagement with the user in the relevant context. (Holtzblatt and Beyer, 2014)

Contextual inquiry, the field data gathering technique of contextual design allows to get detailed information about the circumstances of life; about how people conduct themselves in the day-to-day life, and how they behave and work. It can be utilized in a variety of life contexts, from work, on the way, or wherever people's activities are taking place. (Holtzblatt and Beyer, 2014)

Contextual inquiry guides the researcher when going out to the field and helps to immerse in these circumstances without the need for users to articulate them. By utilizing the contextual inquiry technique, it is also possible to gather information from users in a retrospective manner, by them telling about what has occurred in the recent past, by using context related artifacts and by having them recreating practices that will remind them how something has occurred. (Holtzblatt and Beyer, 2014)

Contextual interview

In the center of a contextual inquiry lies the ability to observe and participate with the user in the relevant context. When the researcher is in the field, an interview is conducted with the users at the place where they live or work. The focus of the interview is put on

the different aspects that are relevant to the focus of the research. A contextual interview should be based on four principles that will help guide it. (Holtzblatt and Beyer, 2014)

- *Context*: understanding the context by observing what the users are doing during the activities and discussing what they do together. Special attention should be paid on the larger context of what users do and how it fits in their lives. Using retrospective accounts and allowing users to retell about events from the recent past can uncover important stories that happened previously outside the scope of the interview.
- *Partnership*: it is essential to collaborate with users to understand their opinions and motivations behind their activities by letting them perform them and letting them provide comments about these activities. It is then important to follow these activities, observe and ask necessary questions about their nature. Keeping the conversations open in addition to asking planned questions is important, as it lets users to lead the focus of the conversation to the most important points in their activities.
- *Interpretation*: the meaning of user's words, emotions and behavior should be determined together with the users. Sharing the interpretations with the user and receiving feedback could help modify and correct initial assumptions and yield a better the understanding of the context.
- *Focus*: determining the focus of the research before going to the field is important. One should keep the discussions on relevant topics, while ignoring aspects that are not meaningful to the scope of the research. Letting users know what is relevant to the research and what is not is a key step. (Holtzblatt and Beyer, 2014)

To summarize, running a contextual interview helps researchers to focus on the aspects that matter the most from the perspectives of various users. The result of the process is design data that lets researchers to immerse themselves in the specifics of tasks carried out by users and yield a far greater understanding of their emotions, motivations and how those fit the larger contexts. (Holtzblatt and Beyer, 2014)

2.4.2 Data analysis

The result of the contextual inquiry is *design data*, which is low-level detailed information that sheds light on the practice of the users in the observed context. More so, it demonstrates how technology is used within it. (Holtzblatt and Beyer, 2014)

The next step after the contextual interview, where the researcher has gathered data, is to analyze it to form an understanding of the context in the wider perspective of life. Each interview provides the insight of one user, and when they are combined together with other perspectives, it leads to a wider and richer collection of insights. (Holtzblatt and Beyer, 2014)

Shortly after each interview, the collected data from gathered notes and recordings should be memorized. The researcher should be able to tell the story of each user after the interview. The aim is to capture key issues related to users' practices, their cultural or identity observations, successes and failures of using tools and other activities, repeating patterns of activities, how time, place and tools are utilized, new design ideas, and other issues that might be relevant to the focus of the research. At this stage it is possible to use different Contextual Design models (such as *task analysis)*, that capture the most important aspects for participants at their work or lives and form a structure of their activities.

Analysis work done within research teams allows multiple people to "brainstorm" together. One researcher acts as a "recorder" and several others act to capture information to the Contextual Design models. The discussion can also ignite design ideas that can be written on notes. (Holtzblatt and Beyer, 2014)

2.4.3 Data consolidation and coding method

In this phase, the in-depth data collected in the contextual interviews and analyzed beforehand is put together into a combined coherent view of the users. This will provide an overview of studied contexts by organizing rich and detailed data, while demonstrating the key issues and the most fundamental structures of life and work activities. (Holtzblatt and Beyer, 2014)

The organization of rich data by teams is commonly being done by the creation of an *affinity diagram*. The affinity diagram helps to represent the most pressing issues that are related to the studied context. The structure of the affinity diagram simplifies the complex data and keeps rich details that were collected from the field. The diagram is to be composed from notes that were created after each contextual interview to sort out the meaningful data that was already analyzed. (Holtzblatt and Beyer, 2014)

The notes are then organized according to different themes to form various groups. The groups arise from the data itself and are not predefined. The process of sorting out the issues forces to investigate each interview separately and think about what each issue signifies in the context. The affinity diagram should be built in a hierarchical manner that tells the story of the issues from the top down. (Holtzblatt and Beyer, 2014)

3. Methods

The general aim in this thesis is to seek a better understanding of the special circumstances under which the interaction between mobile workers and mobile phones is taking place and of the limitations affecting it. In order to accomplish the general aim, a field study was conducted to answer three main research question. The field study was conducted firstly by focusing on the case study of M-Reporting and the reporting process and secondly, by observing the general use of mobile technology by mobile workers.

The contextual inquiry technique introduced in Section 2.4 was adopted to guide the field study. The purpose of going to the field was to gather insights, emotions, design ideas, retrospective experiences and stories about past events from real mobile workers. The data from each contextual interview was collected and analyzed.

The following chapter describes the research questions in Section 3.1 and the study context in Section 3.2. Section 3.3 describes the study cases, the participants and the their equipment. Moreover, Section 3.4 describes the procedure of the field study, the materials used and how data was collected during its conduct. Lastly, it describes the data that was collected and how it was interpret and analyzed.

3.1 Research questions

This thesis aims to answer three main questions:

Q1. What are the unique circumstances under which the use of mobile phones for the purpose of reporting by blue-collar mobile workers occurs?

This is the main research question of this thesis. To answer this question, a field study guided by a contextual inquiry was planned and conducted among workers in three contexts of blue-collar mobile work.

First, within the study context, the aim of this research question was to gain a better understanding of workplace demands to report information and of the reporting practices carried out by workers in the wider context of blue-collar mobile workplaces. Second, it aimed to understand how aspects such as team work, collaboration, coordination of organizational activities and others are manifested by the use of mobile technology.

To answer this question, the findings from the field study were analysed by using the space and place theory introduced in Subsection 2.3.1 (Vartiainen and Hyrkkänen, 2010). The analysis aimed at demonstrating for what purposes physical and virtual (devices and tools) spaces were used and how social and mental aspects such as well-being and stress were expressed through these spaces.

Q2. To what extent do possible limitations affect the use of mobile phones by blue-collar mobile workers for purposes such as reporting in remote and mobile environments?

The second aspiration was to find out how do different limitations and usability issues affect mobile workers when using mobile phones in mobile work for general work-related purposes and for the reporting purposes. The field study has focused on how spatial, temporal and contextual factors affect work carried out in the field. These factors were used to analyze and sort the findings according to their thematic contents. The effect of usability issues on work was explored through the six images of usability proposed by Hertzum (2010). The usability analysis has focused on determining the most dominant usability images to affect the reporting process through M-Reporting within the field.

Q3. Can the conduct of a contextual inquiry suggest new ways to cope with such limitations?

The third aim was to learn whether the conduct of a contextual inquiry can tell about possible solutions stemming from the field. This secondary research question assesses the validity of contextual inquiry in yielding new design ideas from the field.

3.2 Study context

3.2.1 M-Reporting

M-Reporting is a mobile and desktop-based reporting enterprise system developed by *ProTieto Oy*. ProTieto provides reporting solutions for organizations who employ mobile working professionals in different fields. M-Reporting is a cloud-based system that was designed to monitor the data-flow of large enterprises. Field workers enter data that flows upstream through a mobile-based application. This data is later monitored and registered by middle managers who sit in offices and depots. Finally, the data is used by office workers and managers to perform administrative tasks such as coordinating, invoicing and calculating salaries.

The mobile application (see Figure 1) is utilized by workers in various types of field and remote work, from personnel operating heavy equipment to employees performing light maintenance and cleaning duties. The application was created to allow mobile workers the freedom to report important information upstream from the field itself, when workers are remotely away from their main office, either static or on the move. More so, it aims to solve common organizational issues present in the process of reporting by bringing about a digital way to report information.

The digital method of reporting is to replace traditional reporting methods, such as paper-based forms, e-mail messages and other common practices held in mobile work. Digital reporting offers a collaborative element as well, as it enables the possibility to communicate messages directly to supervisors and to other functionaries.

M-Reporting overarches a list of features that can be used in many constellations, and therefore, holds the capacity to be customized to suit many organizational needs and a wide variety of tasks carried out by field workers. The array of features offered to each mobile worker is tailored to the assignments they carry out.

M-Reporting serves enterprises of different calibers all over Finland in different fields of work. The interface is configured differently for each of the enterprises to answer particular demands in relation to the field. In order to well adapt in each case, a collaboration between the service provider and organization is made to configure the system to tailor the interface to the requirements of their missions, to match the number of work contexts and their changeable tasks.

The features are customizable down to the level of individuals. It allows to match features to the capabilities of specific workers. In such cases, some elements can be controlled and made visible to only few selected workers. This is to prevent errors in the process of reporting by, for example, less experienced users.

Mobile workers in the context of this study utilize M-Reporting in Finnish to send reports that comprise information regarding their working hours, task fulfilments, hazards, location-based data, images and documents. They are also able to send notifications to their foremen, maintain site diaries and other activities. Filled reports can potentially be sent from anywhere, both on and off-site, at any given time.

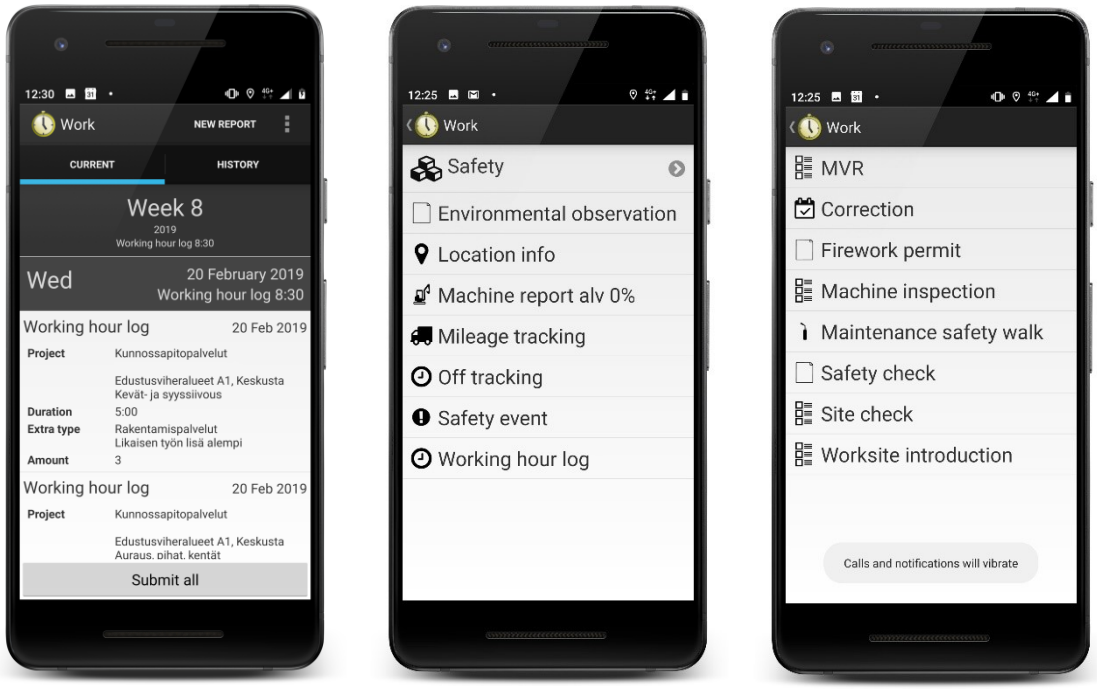

Figure 1. M-Reporting's main view (left) and features list (middle and right) in English. M-Reporting is used by Tampereen Infra's workers in the same configuration but in the Finnish language.

In the daily operations management of the organization, information reported by workers is collected and used to monitor the operations ran by the enterprise. A desktop-based system was designed to serve the administrative side of the organization. Middle management sit in the office and access the system via web browser and administrate

different tasks. These tasks revolve around central data that is used to invoice, gather statistics, calculate costs of projects, distribute and assign work, track work statuses, register materials, provide quality assurance and more. As a result of digital reporting made through the system, much of the paperwork is diminished by field and office workers alike, as no paper is involved in the process of digital reporting.

3.2.2 Tampereen Infra: a data-driven blue-collar mobile workplace

In this thesis there is an investigation of three mobile work cases in one organization. The work cases represent various contexts of mobile work that are carried out within the cohorts of *Tampereen Infra*. The organization provides mobile and construction services within the municipal area of the city of Tampere. Its mission is to "design, develop, maintain and improve the living condition of the residents of Tampere and the surrounding area" (according to Tampere city's official webpage[1]).

The multifaceted organization is first and foremost responsible for the upkeep and the development of streets, green spaces such as parks, forests and gardens, and as well as for the maintenance and renovation of public beaches, playgrounds, sport facilities and others. In addition, it provides spatial data, internal, administration and support services. The organization has agreed to participate in this study by allowing access to its workers.[2]

The diffusion of ICT based solutions and better equipped vehicles that use GPS information when carrying out many of the operation missions have contributed to the efficiency of the organization by saving time, costs and work hours. The digitization process has contributed to a better targeted maintenance operation. For example, it is considered to be the main contributor to reducing the amount of dry salt poured in the streets of Tampere during the winter months, from 1,300 tons during 1980s to only a one sixth of that quantity nowadays.[3]

As part of the enterprise's digitization process, the M-Reporting system was procured and diffused during 2014. Prior the procurement of the system, some of the administrative duties were carried out manually by using paper. Registration of working hours was done by using paper sheet forms that were distributed among workers. Registering the working hours was carried out by office workers who digitized the information to the system. Currently there are approximately 450 workers in Tampereen Infra who utilize the M-Reporting mobile and desktop-based system.

3.2.3 Deriving the workplace reporting demands

The M-Reporting system is used in both office and field work settings. The purpose of the system is to gather data about the work tasks in the field. The workers are requested

[1] Tampereen Infra's Mission and Vision, *Tampere city's official webpage.* Accessed March 06, 2019. https://www.tampere.fi/tampereeninfra/yleista/missiojavisio.html

[2] This cooperation was made possible by the assistance of ProTieto Oy.

[3] Tampereen Infra "Tie ja Liikenne" magazine https://www.tampere.fi/liitteet/i/659SOXKCy/Infrajuttu_Tie_ja_Liikenne_lehdessa.pdf

to report various types of data in relation to their line of work. Therefore, the system offers many features that are directed to gather data that is related to their tools, vehicles and equipment used in various roles in field work. In addition, some features are directed at supporting the administrative process of billing, invoicing and payment of salaries.

The monthly chart (see Figure 2) illustrates the distribution of the types of reports by workers in the enterprise. The most common report types among workers are driver and working hour logs. The third most common report type is used for accounting of machines used in various assignments. The chart includes other types of reports that are used by all contexts of work in the enterprise. The chart illustrates that other types of report were used in rather limited frequency.

In the reporting process, workers are requested to fill digital forms by drilling down lists and selecting information in different sections. The application receives this information via the enterprise software through which desk workers manage the internal operations. The information is edited by managers and then automatically fed to the server and made available to be selected from the interface. The content of filled reports is sent to the approval of foremen. Once reports were approved by foremen they are automatically sent to the database and used to monitor work, to pay salaries, to receive statistics and to calculate costs of supplies, subcontractors and others. The most common report feature that is used by mobile workers is that of *working hour log*. In the working hour log feature, they submit daily working hour quotas by filling out electronic forms.

In the process of working hour reporting, workers are required to drill down through several lists and select information that is relevant to their assignments. Such information includes names of responsible foremen, locations and types of work that were carried out, and finally their own time stamps. It is optional for workers to adjust the time and date of the forms, so reports can be sent ex post facto or in advance. It is also possible to input

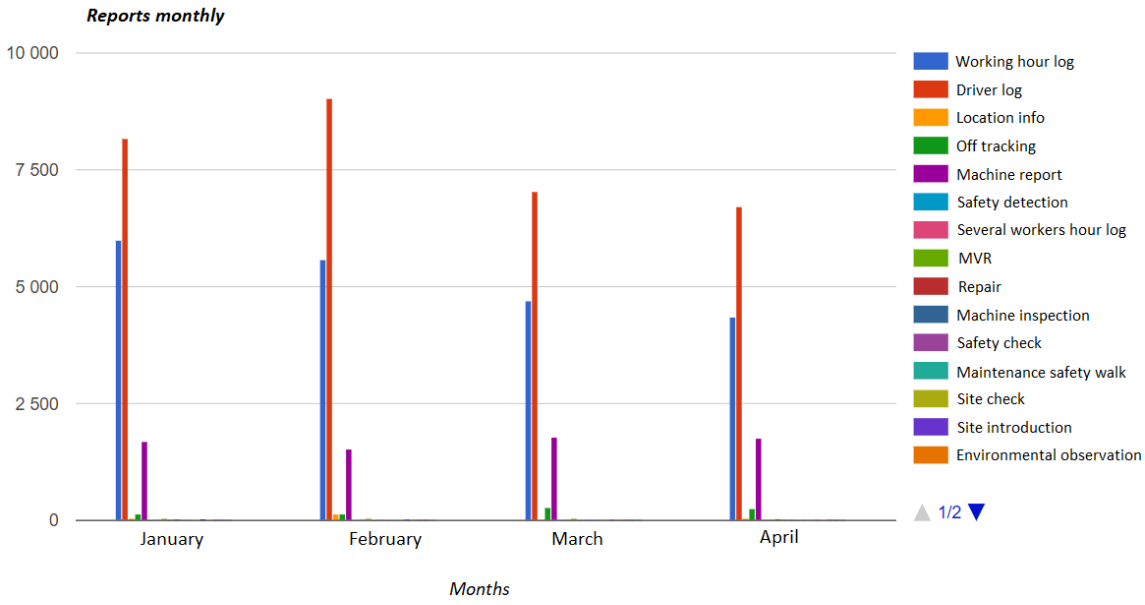

Figure 2. Monthly distribution (January-April) of reports chart by field workers of Tampereen Infra.

information about extra hours, provided some were carried out. The information workers are required to report is dependent on the type of work they carry out.

Reporting responsibilities in different contexts of work

There are common work-related reporting procedures that workers are required to perform by utilizing mobile phones as part of their work (see Table 5). To understand the reporting practices among mobile workers, these procedures were investigated. Prior to the field study it was known that there are three main features used by workers over the cases. Therefore, during the field study the focus was put on observing and interviewing workers about the following reporting procedures listed in Table 5.

Case	*Report features*	*Description of main reporting feature*
Case 1	Within the group of drivers, workers were observed performing working hour logs and driver logs reports.	*Driver log:* reporting of different parameters related to driving errands, such as distance, volume of goods loaded to cargo beds, type of material, cargo origin and destination, etc. The minimum requirement is a submission of four reports each day. The information is used by the organization to estimate costs of resources, payment for subcontractors, etc.
Case 2	Within the group of maintainers, workers were observed performing working hour logs and safety detection reports.	*Safety detection:* reporting safety events by workers. The worker can fill out a description for the event and attach images. Location is automatically added. Report is sent to site managers to be further resolved.
Cases 1-3	Within all cases of work, workers were observed performing working hour logs.	*Working hour log*: reporting how long the worker has worked during the day. There can be multiple hour reports during one day. Workers are paid by the hour, so the task of hour reporting is standard protocol.

Table 5. Observed reporting features in the field study.

First, participants were asked about the working hour reporting feature to learn about how reporting for administrative purposes is carried out. The task of hour reporting is a standard protocol to all field workers within the organization and could shed light about how workers with different roles handle a similar task. Therefore, workers from all cases were asked and observed, when possible, about the working hour feature. Second, in Case 1 the use of Driver log feature was explored to understand the practices of reporting data from the field when carrying out driving errands. Third, in Case 2 the use of the safety detection feature was explored to understand the reporting practices from the field when carrying out maintenance tasks.

Working hour log description

To issue an hour report, workers are first required to log into the application by using their own personal credentials and press on *new report* to create a new form. A list of

report features launches with all the reporting options available to use. A report form that contains a list of rubrics then opens. The top rubric is that of the *project selection* and selecting it will open a view where a nominal list of departments is presented. Each department is presented together with its designated code number.

During the project selection phase, the worker can proceed by selecting an option from the list. This is made by touching the relevant item on the list. Pressing on an item automatically forwards the worker to a second list of items, where workers select a *responsible manager for the performed work,* and then a third, where the *work area* is selected, and lastly, a fourth list, where workers select the *type of work* that was performed. When the type of work was selected, an OK button is made available to be selected. Pressing it will close the project selection view and a summary of the selected information will be logged and presented in the rubric. This information is made editable by pressing the project selection rubric again.

In each segment in the project selection view the number of items available to be selected from the list varies. One list can contain a single item or as much as dozens of items in one view. It is possible to manually scroll down the list or conduct a search from the available search bar at the top right-hand side of the screen. In this way it is possible to narrow down the list of items to fewer. It is possible to navigate between the views by pressing the *back* button, to edit the selections.

The next phase is that of editing the *time stamps* (see Figure 3 right) and is made by editing a *start* and a *finish* time. The time can be logged by pressing arrow buttons up and down to edit the desired hour, and minutes alike. This process is made twice during one report; once for the start hour and once for the finish hour.

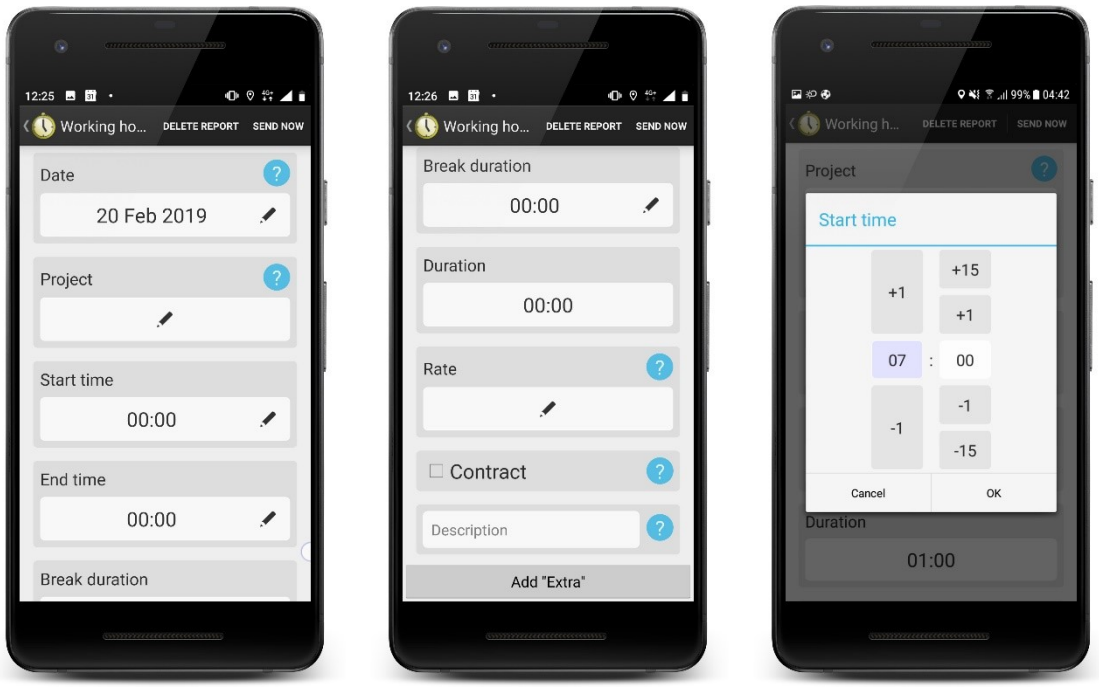

Figure 3. Working hour log feature. Form (left and middle) and time stamp edit (right).

More information that can be logged in one report adds *wage factor, extra hours, contract related information, a description,* and the *date.* The date of the report appears automatically but can be edited to mark the hour in a retrospective manner or in advance.

Driver log description

All drivers are required to use the driver log feature (see Figure 4) to send information in relation to their driving errands. Such reports can contain information about the cargo; the type of material and supplies that are being delivered and the drop point of these. For example, a truck that carries soil that was dogged from a construction site and delivers to a dumping site somewhere else. In addition, the feature is used for the billing of contractors who provide mobile services.

The idea is that after a task was carried out, a driver can log into the application, create a new report, enter the time stamp, add the measurement of the cargo and its quantity, add the type of material and the location of dumping sites, and submit the report. Maintenance drivers log in and report information about the time stamp, vehicle that was used for the task, the type of task that was carried out and its location.

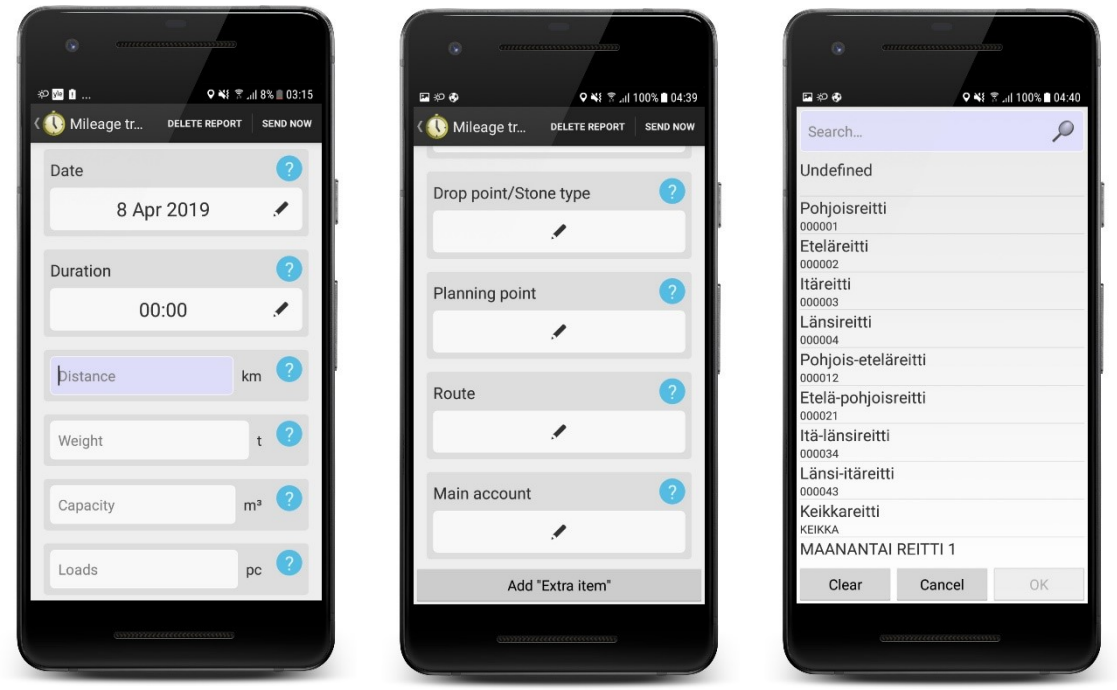

Figure 4. Driver log feature for driving errands. Report form (left and middle) and list of routes (right).

Safety detection description

With the safety detection feature (see Figure 5) it is possible to send reports to foremen when workers have located issues within the environment that require to be taken care of. This feature can be used by different workers, but primarily by workers who carry out maintenance related tasks when out in the field.

To issue a safety detection report workers log in, choose the level of urgency and the type of the event. A description and an attachment to the report can be added as well. The location of the event is added automatically.

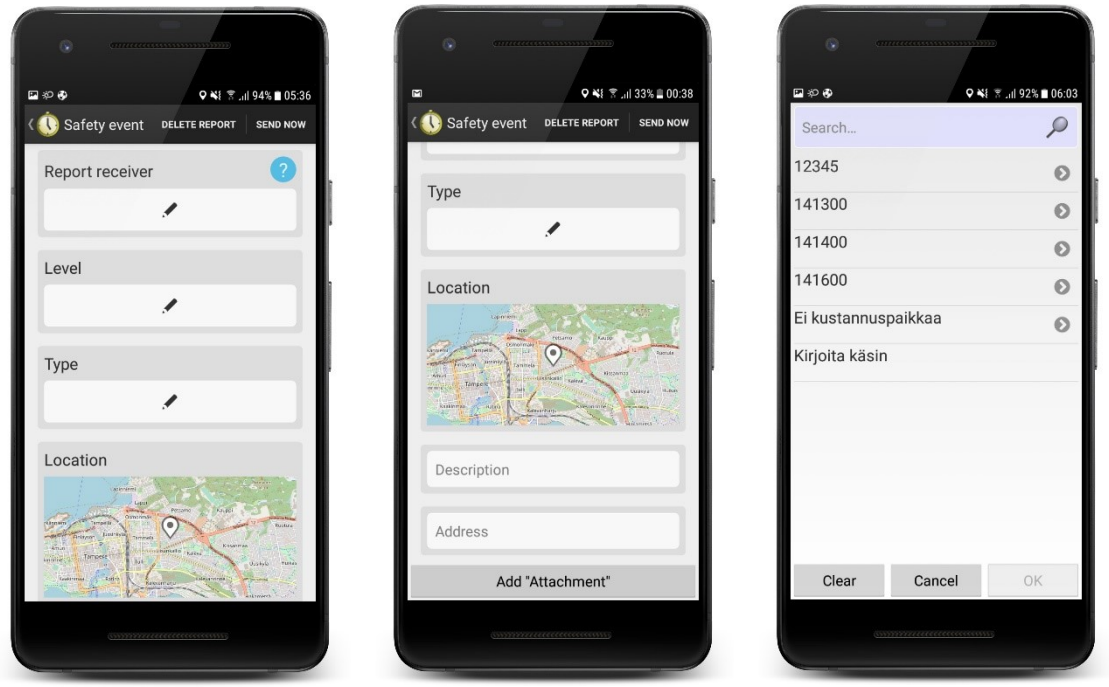

Figure 5. Safety detection feature for maintenance work. Report form (left and middle) and list of receivers (right).

3.3 Mobile work cases and participants

3.3.1 Three mobile work cases

In this thesis there is an investigation of the three mobile work contexts described in Table 6.

Case 1 (n=5) is comprised from four maintainers and one foreman. Maintainers carry out maintenance work all around Tampere area. Their tasks are divided into two main parts: in summertime it mostly consists of landscaping chores, whereas during wintertime their work consists of street maintenance chores such as snow and ice removal. Their foreman acts as a middle manager whose responsibility is to monitor work, coordinate working schedules and administrate the data-flow of workers. For example, such tasks are approving work hour logs and answering safety detection reports. The field study in Case 1 was conducted in four different locations around the city; in one site office, two permanent offices and one depot.

Case 2 (n=4) is comprised from drivers who run driving errands in two different work contexts. Two drivers were running road maintenance related errands and two drivers participated in construction work. The field study in Case 2 was conducted on the road and in two different construction sites.

Case 3 (n=3) is comprised from two construction workers and one foreman. They carried out construction related chores in two different construction sites. Case 3 consists of one construction worker, one excavator operator and one foreman. Foreman is a middle manager who monitors and coordinates work carried out in the field and administrates

the information flowing from workers while sitting in the site office. The field study was conducted in two construction sites.

Case and number of participants	*Description of the cases*	*Time period of study in 2018-2019*
Case 1 (n=5)	Case 1 is comprised from four gardeners and one foreman.	December - January
Case 2 (n=4)	Case 2 is comprised from two construction truck drivers and two maintenance drivers.	October - January
Case 3 (n=3)	Case 3 is comprised from two construction workers and one foreman.	February - April

Table 6. The three mobile work cases of the study.

3.3.2 Participants and their used tools

An overall number of 12 participants were taking part in the field study. 10 out of 12 of the participants have been recruited by their corresponding department managers and two participants were recruited in the field. Their contact information was provided to me separately by department managers upon request. An additional construction worker, a measurer, was interviewed in situ in construction site 3 - office, on April 10th 2019. However, he was not asked to provide background information due to not using the M-Reporting system to report.

The participants were constituting three different target user groups participating in the research, and they represent three different contexts of mobile work. A sample of at least three participants for each case was selected to form three groups of participants (see Table 7 on page 34 for participant demographics).

Seven participants were males and five participants were females. Four participants were between the ages 50-54 and four participants were between the ages 60-64. Two participants were between the ages 45-49. One participant was between the ages 25-29 and one between the ages 40-44. The average age of the participants was 51. All the participants spoke Finnish, which was used as the language of communication during the field study.

Equipment and technology used by participants

A very diverse inventory of mobile and stationary equipment was either in use or demonstrated by workers within the field. Maintainers were utilizing all sorts of machines. Drivers were using different types of vehicles such as snow-ploughs and dump trucks, stationary terminals and in-car radio transceivers. Construction workers were using and demonstrating how they use two-way radios, real-time kinematic sensors and poles, GPS, drillers, cutting discs, ground levelling machines and excavators. Participants utilized and discussed the use of documents and other paper material such as maps used

at their work. Equipment and other materials that were relevant to the focus of the study will be discussed in detail in Chapter 4.

Participants utilized mobile phones in different spaces, within and outside the field.

1. Work designated smartphones were rather basic Samsung smartphones that were provided to workers by the organization. and used for work related purposes, such as: reporting, communicating during work and outside of work hours, use of other work-related applications and other installed features.
2. Some participants used or demonstrated how they use their privately-owned mobile phones during the interviews. The privately-owned mobile phones were of different brands and were sometimes in use for work-related purposes which will be discussed in Chapter 4.

In addition, one participant used a work designated tablet, which is used in construction work mainly for satellite navigating technique work and for free use in the office site.

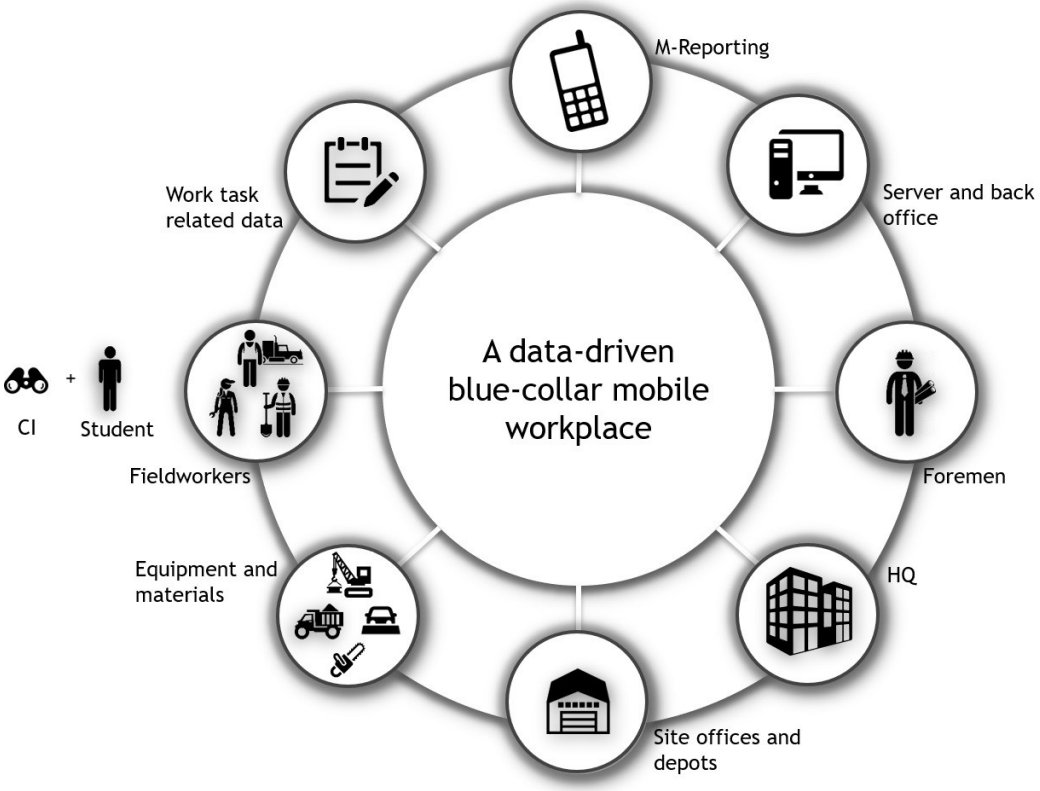

Figure 6. An overview of the study context.

Participant codename	*Age group*	*Gender*	*Role*	*Duties carried out*	*Equipment used and demonstrated*	*Technology in use*	*Meeting place*	*Date of interview*
Maintainer 1	40-44	Female	Gardener	Maintenance duties, waiting at office, driving to depot	All-terrain vehicle	Work and private mobile phones	Site office 1	19.12.2018
Maintainer 2	50-54	Female	Gardener	Maintenance duties, waiting at office	Did not use nor demonstrate any	Work and private mobile phone	Depot	20.12.2018
Maintainer 3	45-49	Female	Site Manager	Receiving calls and visiting workers	Did not use nor demonstrate any	Desktop computer, work and private mobile phones	Depot	20.12.2018
Maintainer 4	60-64	Female	Gardener	Maintenance duties, waiting at office	Did not use nor demonstrate any	Desktop computer, work and private mobile phones	Permanent office 1	11.01.2019
Maintainer 5	60-64	Female	Gardener	Maintenance duties, waiting at office	Aerial map	Work and private mobile phones	Permanent office 2	02.01.2019
Driver 1	25-29	Male	Truck Driver	Driving errands of loose material	Dump truck	Radio transceiver, work and private mobile phones	Construction site 1 - field	29.10.2018
Driver 2	50-54	Male	Maintenance Driver	Snow and ice removal, salting, sanding, driving	Snow plough truck	Stationary terminal, radio transceiver, work and private mobile phones	On the road	07.01.2019
Driver 3	60-64	Male	Maintenance Driver	Snow and ice removal, driving	Snow plough truck	GPS based mobile application, radio transceiver, work and private mobile phones	Main office	08.01.2019
Driver 4	50-54	Male	Truck Driver	Driving errands of loose material	Dump truck	Radio transceiver, work and private mobile phones	Construction site 2 - office	06.02.2019
Construction 1	60-64	Male	Builder	Measuring, levelling	RTK pole, levelling machine, driller, disc cutter, aerial-site maps	RTK sensor, tablet, cloud service, work and private mobile phones	Construction site 2 - office	05.02.2019 06.02.2019
Construction 2	50-54	Male	Site Manager	Monitoring work, receiving calls, approving reports	Enterprise software, reports and other documentation	Work and private mobile phone, desktop computer, enterprise software	Construction site 3 - office	20.03.2019 10.04.2019
Construction 3	45-49	Male	Excavator Operator	Excavating, driving	Excavator, site map, GPS system	GPS system, private firm's mobile phone	Construction site 3 – field	20.03.2019

Table 7. Participants taking part in the field study.

3.4 Field research materials

Materials were used in the field research for data gathering purposes. I wrote these materials first in English and they were later translated to Finnish by a Finnish native speaker to be used in the field. First, an informed consent form (see Appendix A) was used to receive participants' consent to participate in the field research. A background questionnaire (see Appendix B) was designed to gather participant demographics.

Background questionnaire

In the background questionnaire participants were asked to provide data about their personal and work role characteristics to represent the target population used as a sample in this study.

Familiarity of participants with the M-Reporting application was asked to learn to what extent, workers and their work are affected by the level of experience they have with the application used for the purpose of reporting.

How often participants have used the M-Reporting application for the purpose of information retrieval and *for actual reporting purposes*, were asked to help determine the manner of which the use of the application is taking place. This information was generally used to understand the frequency workers have used the application during working times and how often it was used for other purposes.

What kind of reporting features each participant performed as part of work, was asked to help establish what features are more familiar and usable by the different participant group and learning about the demand to generate data. A higher number of features could possibly mean higher demand to utilize mobile technology during work. During the interviews, participants were asked about the frequency of use of each of the features to establish an understanding of reporting habits, attitude towards particular features and possible usability issues affecting their use.

Whether participants have encountered a problem while using the M-Reporting application in recent time, was asked to learn about whether there were any recent general or usability issues with the system, what kind of issues have occurred and how participants have solved them.

The background questionnaire, together with the consent form, were handed to participants in the beginning of each contextual interview with one single exception, where a verbal consent was asked prior to the interview and the signed consent was given later.

Equipment used for data collection

To capture the entirety of participants' insights, experiences and stories, I used a digital voice recorder (Olympus WS-811) to record conversations that were held during the contextual interviews. Two conversations were not recorded, due to logistical reasons. Recorded conversations were later listened to and findings were summarized in a

spreadsheet that I have maintained to collect key issues that have appeared in each interview.

During the interviews I used a notepad to write down key notes while conversations with participants were ongoing. The notes were later used as a diary and served the process of summarizing the findings and helped in reconstructing important parts of participants' stories. Some of the written notes contained details such as brand names and others, with intention to look for more information and to learn about contextual work factors, to remember relevant facts and to reconstruct stories that were thought to be of relevance to the focus of the research.

To capture any possible usability issues within the M-Reporting application, the rear camera of my Samsung Galaxy A3 smartphone was used to video record the reporting process by participants. I started to video record only after I have received a verbal and a signed permission to do so. The video recordings began when a participant informed about the intention to report and ceased when the process ended. The recordings were used to learn whether there are any apparent usability issues with the M-Reporting application and to determine how possible usability issues may affect the reporting process or work. Since participants did not have an intention to use the M-Reporting to report during every field study, recording was made possible with only seven participants.

3.5 Procedure of field research

The contact information of nine participants was provided to me by their managers in several manners, such as through phone calls, e-mails and the help of ProTieto. Two additional participants were recruited by using the snowball sampling technique (Patton, 1990) in two different sites.

3.5.1 Coordinating the field study

To set up the field study, I called participants whose names were provided to me, shortly introduced my thesis and the aim of the research and verbally provided an invitation to take part in the research. The two additional participants who were recruited in the field study were introduced to me by workers who were already interviewed. One participant was interviewed during the following day and one participant was interviewed right away.

Coordinating meeting times

After participants had given me a verbal consent to participate in the field research, a meeting time was set. The meeting times were booked to suit the working schedule of each participant, and they were mostly in times that were convenient enough for workers to meet without interference to work. For instance, during morning coffee breaks between 8.45-9.00 AM, and during lunch times, between 11.30-12.00 AM at noon.

Coordinating meeting places

The meeting points were then coordinated together with each participant. Meetings with construction workers were set to happen at places, which were largely temporary construction sites situated in the city's outskirts. The sites were often within the terrain of industrial zones or newly built neighborhoods, yet rather close to populated urban areas that could be reached by public transportation.

To coordinate the meeting points, participants were asked to provide directions to the working sites, which required to be very specific as construction sites do not have exact addresses. Therefore, often participants have given name of streets in the vicinity and elaborated more by using geographical descriptions to help physically describe the locations of the sites.

Meeting points with construction workers and drivers who participate in construction duties were set at the construction sites' offices. Meeting points with maintenance workers were set at their booths and permanent offices inside the city and were easier to coordinate due to their relatively central locations. Meeting points with maintenance drivers were changing and could be more fluidly arranged. One driver volunteered to meet me at a strategic point on the driving route close to my home. We met at a gas station close to where I live. One field study began at the maintenance department's central office during a morning coffee break.

3.5.2 Preparations on the arrival at the field

Upon arrival to few meeting places, I was required to make a second phone call to verify the exact meeting points. Further information that was given by participants to describe their whereabouts was, for example: "*You can find me by that big blue truck*", or "*The booth is 100 meters after the bridge*". Similar descriptions were sometimes given during the first calls made to participants. On few cases, during the day of a field study, it was agreed that I will make a phone call to participants shortly before scheduled meeting times, this is to inform about my intention to arrive in advance.

Upon the on-site encounters, the way introductions were made varied between participants. Introductions with maintainers were mostly made close to their offices. Some were made outside and continued inside the office. Some have initially started inside the offices and stayed there. Introduction with one maintenance driver was made in a parking lot and continued inside a snow-plough cabin. The introduction with another maintenance driver started at an office and continued inside a cabin of a snow-plough. Introduction with construction drivers were made at the construction site.

During the introductions, I gave a short brief about the field research procedure. It was explained that the objective of the field research is to learn about the use of mobile phones and the reporting process as part of their daily work routines and possibly to observe them interact. It was also explained that in addition to the observations, I will ask the participant questions about mobile phones use and the reporting process using the M-

Reporting application. Participants were also asked to share their past experiences or any information they thought relevant about mobile phones' use and the reporting process itself.

After the introductions, participants were asked to sign an informed consent form and to fill a background questionnaire. Participants were asked, when feasible, to describe what was taking place while reporting. Only after participants said to understand the procedure, the digital voice recorder was activated to record proceeding conversations.

3.5.3 Interview and observation focus

The conduct of the contextual inquiry in the field can be seen to have two main features, a contextual interview and an observation. Running a contextual interview allowed me to engage in conversations with workers where they work and rest. My field interviews ran based on the four principles that were introduced in Section 2.4. (Holzblatt and Beyer, 2014).

Context: in the beginning of each interview, an emphasis was put on understanding the role of each worker by asking them to tell about their daily work routines, weekly schedules, tasks they are in need to perform and how they are informed of those tasks.

A second emphasis was made on understanding the role technology has in such work routines. Participants were asked about their experiences using mobile phones as part of their work. Telling retrospective events essential when work could not be observed, for example, in the case of maintainers.

Thirdly, participants were asked to tell about the kind of tools, equipment and how those are used within their work. In some interviews participants have willingly demonstrated part of their tools.

Interviews conducted with foremen focused on gathering information about their roles, the responsibilities of their subordinates and about the operation itself. It focused on understanding what kind of job demands there are regarding the use of technology by workers for data creation. More so, what kind of data workers are required to provide and how it serves foremen and the whole operation. In addition, foremen were asked about any possible issues due to use of mobile phones or due to data gathered and whether it imposed any issues on workers themselves. Lastly, it focused on understanding how work conventions may affect work practices and reporting habits carried out by workers.

During the interviews I asked several important questions to learn about the use of mobile technology and the reporting process. Additional questions were made to learn about forms of collaboration workers are having with each other and what tools are used for communication and collaboration purposes.

To use retrospective accounts, participants were asked to recall whether they have personally experienced any issues with mobile phone use in the past that may directly or indirectly affected their work or the work of others.

Partnership: given the diversity of contexts of work, the process of interviewing and collaboration with participants tend to differ from one participant to another. The ability to conduct a contextual inquiry and witness participants perform physical work was only possible in eight of the cases.

In the study case of drivers it was possible due to the fact that the interviews were held in the front cabins of the vehicles they drove. Drivers could demonstrate their work and discuss about it openly while carrying out different tasks. In the case of maintenance workers it was not possible as it appeared that the daily capacity of work was already performed earlier in the day and later workers had to stay put inside their work stations during the times of the interviews. Nevertheless, it was possible to learn about their work through stories and by maintainers leading me through their descriptions of day-to-day events. Construction workers were interviewed at two different sites and were very fluid.

The condition in the field occasionally affected the ability to converse. Interviews with maintenance workers were assisted with no interruptions, aside to few phone calls made to workers and random visitations of peers and managers. Interviews with maintainers were a key to understand their work context, because it was not possible to observe them performing actual maintenance work during the field study. In the study case of drivers, I had to take measures of caution and tried not to distract the drivers in performing their work, for example, in cases that there were pedestrians in the vicinity of the vehicle or when they were converging main roads. In these situations, I tried to stop talking and continued only when road conditions seemed more appropriate. With construction workers conversations were made possible during coffee and lunch breaks in the offices. These conversations sometimes extended outside of the offices to digging sites, where some workers demonstrated the use of work tools that were mentioned earlier during interviews.

Interpretation: to determine the correct meaning of participants' stories and words I sometimes asked workers to further clarify what they meant and to provide examples from past events. An emphasis was made towards understanding the emotions and attitudes of workers towards different aspects of work and in particular, the use of mobile phones and the reporting process.

Focus: the emphasis during the beginning of each interview was set on letting participants know the scope of the study. The process started off by having a regular interview that proceeded to be informal as soon as participants seemed to understand the aim of the study. At this stage, interviewees steered the conversations to issues that matter the most to them. From time-to-time I shared my own insight and understanding of the issue to be on same page.

The aim of the observations was to have a closer look on what workers do as part of their work, how they carry out tasks, how tools, mobile devices and artifacts are used in their contexts. When possible, I observed participants performing their duties as part of the workday routine. The observations focused on how workers were carrying out their

work and how equipment, tools and objects were used and mobilized in the field. Special attention was given to workers' communication and collaboration practices with peers through the use of mobile phones and other means. In addition, I focused on the interactions made with mobile phones in field and office contexts. The work environment and how work is affected by it was observed as well.

The second aim was to gather a better understanding of the larger context of work, how workers collaborate within the team, where does the data that they generate go and how it serves other stakeholders in the enterprise.

3.6 Qualitative data collection and data interpretation method

The objective of the field study was to find out the practices in context of mobile phone use by mobile workers. Mobile working professionals were interviewed and observed by conducting a field study guided by the data collecting technique, contextual inquiry in their remote work context. Participants were performing real work such as driving, maintaining and building.

During the observations, when feasible, participants were asked to explain what was taking place during the reporting process. Participants shared their personal past experiences of mobile phone use as part of work and about the reporting process done by using M-Reporting application.

The conduct of the field study has resulted in the collection of notes, voice and video recordings. The voice recorded conversations were listened to again shortly after each interview and were interpreted to determine the main issues arising from participants' worlds that relate to the focus of the research. Notes that were written in the diary during the field study were used during data interpretation sessions to reconstruct important parts of participants' stories. The main findings from each interview were written down in one large document.

3.7 Analysis

The aim of the data interpretation process was to gather a wider understanding of the context of mobile use in remote and mobile environments. The main findings from the data interpretation phase were written down in a spreadsheet (see Figure 7) and grouped according to themes relevant to the focus of the study. Some of the themes were pre-added before the beginning of the study and signify issues that the field study aimed to explore. Most of the themes were added during the field study and represent the most pressing issues that emerged from the interviews. In addition, some themes were added at later stages during the field study and helped to thematically analyze the findings according to the theoretical analysis framework introduced in Section 2.3. Overall, the spreadsheet contained data gathered on 15 themes: mobile phone use, reporting process issues in general, usability issues, reporting habits, reporting features, seasonal issues,

training, digital versus manual reporting, spatiality, temporality, contextuality, physical spaces, virtual spaces, social spaces and mental spaces.

As seen in Figure 7, the rows on the top of the spreadsheet signify the themes and the columns signify the list of participants. Each cell in the spreadsheet matched data collected from a particular participant and grouped under their matching headline.

In the spreadsheet I wrote all the selected information that was gathered during each visit in the field. The leftmost column was used to list the participants by their given codenames. The top row was used to host the main issues emerged from the field. These were finally used to summarize the results and formed the initial headings during the process of writing the findings. The empty cells in the spreadsheet were filled with the data gathered after each field interview. Mostly, one column was filled at once, since each column summarized the findings from one participant. However, in the process of transforming data from the diary and from the voice recorded conversations more information was sometimes added to different columns at the same time.

This imitates the process of creating an affinity diagram as guided by Holzblatt and Beyer (2014) but discards the use of notes, as the process was not conducted in a team.

Participant demographics that were collected by using background questionnaires and the gathered information were summarized in a table (see Table 7). The data gathered in the background questionnaire assisted in the writing process of the findings chapter.

The video recordings have resulted in gathering qualitative data that was used to locate possible usability problems within the M-Reporting application. The videos were viewed again to learn about the reporting habits of workers.

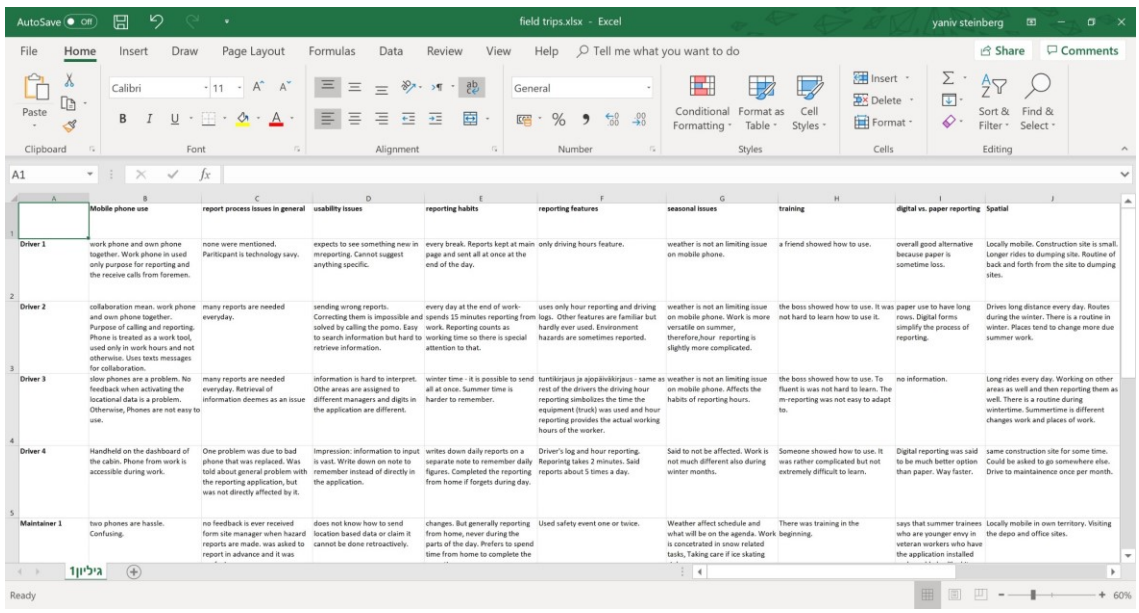

Figure 7. Analysis of the findings made on spreadsheet.

4. Findings

A field study was conducted to learn about the practices of mobile workers, and about how limitations and usability issues affect the use of mobile phones for work-related purposes. The exploration in the field viewed how different attributes affect the context of use of mobile phones for the purpose of reporting and for general purposes required as part of day-to-day tasks of workers.

The following chapter presents the main findings collected in the field study. Section 4.1 demonstrates how the requirement to work from various physical and virtual spaces affect the experiences of mobile workers and the reporting process. Section 4.2 focuses on how spatial, temporal and contextual attributes affect the possibilities to answer demands to utilize mobile and information technology and the reporting process. Finally, section 4.3 discusses the usability of mobile and information technology and the M-Reporting system through the images of usability.

4.1 Spaces in blue-collar mobile workplaces

The three study cases were analyzed by using the space categories presented by Vartiainen and Hyrkkänen (2010). The purpose of the spaces analysis is to understand how the requirement to work in multiple spaces affect mobile workers by exploring how physical and virtual spaces are utilized in practice in three contexts of blue-collar mobile work. Furthermore, the analysis is conducted to understand how requirements to work and interact in virtual spaces and devices from multiple spaces affect the positive and negative experiences of mobile workers.

First, I describe the physical spaces used for work and the purpose of each of these spaces. Second, I describe the kind of virtual tools and devices (i.e. virtual spaces) and how they are used within physical spaces. Third, I discuss the function of physical and virtual spaces as social spaces, where the ties and support of social networks is gathered. Lastly, I discuss how different well-being and mental perceptions in relation to physical and virtual spaces were expressed by workers. The social and mental spaces are discussed together in Subsection 4.1.3 and a wrap-up is presented in Table 8 on page 54.

4.1.1 Physical spaces at the workplace

In case 1, maintainers had the simplest form of mobility. They were required to move between multiple physical spaces during a given day primarily by foot and stay there to carry out various tasks. In case 2, maintenance drivers had the highest degree of physical mobility. They were required to drive their vehicles between dozens and hundreds of kilometers and drive through multiple locations per day. Construction drivers were highly mobile as well, but also tend to move on-site or stay static inside their vehicles. In case 3, construction workers were locally mobile and spent their days in two main locations,

their construction sites and site offices. All workers were required to work, or visit in multiple physical locations to different extents.

There were four main types of physical spaces that workers worked or mentioned to work from during the field study:

Home is where only a negligible portion of work is carried out. Since work is physical in nature and accomplished in the field, it can hardly ever be taken home. However, mobile technology and the demand to report information was found to blur the divide between home and the field, as most workers said they report or communicate from home to different extents.

The task of reporting work hours was mentioned by most workers to be done from home to some extents. Most workers were found to delay parts or the whole data entry or to forget to report from their workplaces. Workers who chose to delay reports said to do so until they arrive home, and fill their reports after workhours or during weekends. Some postpone their reporting tasks by a week or two, accumulate many reports and fill them all at once. One subcontractor said that reporting is sometime carried out at home because other paperwork is done there as well. Furthermore, foremen hold many administrative responsibilities that extend to their homes, such as communicating by the phone and sending e-mails.

In addition, some of the communication between workers and their foremen was said to be carried out from home. This occurs when foremen inquire about the availability of workers or inform ahead about changes in schedule or alternatively, when workers wish to inform about their absence. They either send absence reports via M-Reporting and short message service (SMS) or call by their mobile phones.

Home is where some hour and other reporting tasks are delayed to by workers and some are completed from home. Home was largely perceived as a comfortable place to report from. Workers said that at home there is the possibility to slowly sit down and focus on the reporting task at hand. At home there is enough available time to enter data without interferences as result of intense outdoor work surroundings.

The field is where most work and team collaboration tasks are carried out. The types of work and fields differed between the cases but shared relatively similar elements of an intensive physical environment. As result, workers may suffer from physical fatigue and mental stress. In all cases, the field was a place where there were many tasks to do and little room for slack of any kind.

Work carried out between the cases can be separated into two categories; work carried out in a fixed place and work carried out on the go. The number of places workers were required to visit was subsequently determined by the nature of their tasks.

Such definition requires a different interpretation for drivers as their main work was carried out in the field, yet in various means of transport, e.g. inside vehicles' cabins. The spaces inside the cabins were small and offered some physical constraints for interactions with technology. For example, not all dump trucks were equipped with phone holders,

the space in snow-plough trucks was occupied by stationary equipment, and placement of devices on dashboard and other surfaces was not optimal due to acute movements of their vehicles. Nonetheless, cabin space offered protection from the outside environment and drivers were observed to sit and interact with their mobile phones when parked. Some drivers used the space for reporting or documenting errand related data and kept notes and lists of information in available surfaces besides driver's seats.

Work of drivers was carried out on the go, which subsequently required to briefly visit many physical locations. The fluid movement of maintenance drivers required to skip from one place to another very rapidly. Each of these places brings new events that are needed to be dealt with, some can be fixed in place and some require mediated interaction by resorting to the use of a virtual space.

Encounters with physical locations were less meaningful because they were essentially very swift and repetitive activities. For example, removal of snow from bus bays is rather simple and monotonous. However, although such activities can constantly repeat during each maintenance round, they are carried out while operating heavy vehicles and while paying attention to road traffic and pedestrians. Therefore, it could very well be filled with unforeseeable and unexpected events.

Maintainers were less mobile and therefore their work was carried out from fewer spaces. However, they are required to spend several hours in one location and carry out long maintenance actions on the move or in fixed locations such as gardens and parks in urban environments. Their tasks in the field include crossing between street infrastructures and "green" areas very frequently. For example, cutting grass and collecting litter are activities carried out on the move across large areas with different physical characteristics. There is also a frequent transition between stationary work activities and shorter activities "on the go". For instance, grooming and planting chores are "fixed" and blowing leaves is carried out while walking. The work of maintainers in physical spaces is ultimately dynamic, consumes time and requires attention to detail, which subsequently interferes with the ability to interact with mobile phones. However, the diversity and number of tasks often requires mediation through mobile technology.

Construction workers' tasks were more fixed in the physical sense but required a lot of precision. The exchange of physical spaces throughout their careers is determined by the length of projects. Typically, construction projects last between several months and several years.

In construction work, the environment itself creates many unexpected issues that affect work. As a result, the need for precision and accuracy in regard to the geographical environment is mediated by technology, through which workers gain access to data to help carrying out their tasks. Furthermore, the complexity of work and the dependency on external manpower, and on supplies and materials requires constant virtual mediation with a high number of stakeholders.

Construction workers' mobility is often limited to two main physical locations; their construction site and the office site. However, workers with specific skillsets, such as measurers, are required to visit other sites at the same area. Nowadays, there are less measurers working per area (two, while previously there were four), which requires much more flexibility and improvisation on their part. Further, it requires much more coordination with ground parties at the different construction sites. The strive for accuracy and precision ultimately affects everyone in the construction operation due to higher demands to use measuring devices in the field, to document the work and to inform others about it. In some cases there was presence of foremen in the field. In construction work monitoring the progress of work on ground every day is important.

Reporting information was very rarely carried out in the field. Although it is mandatory for workers to report their hours of work eventually, they are not compelled to do so from the field. This occurs since there are no clear-cut conventions that instruct workers to report immediately after work was carried out, or since workers prioritize work or choose to delay reports. In contrast, reporting driver logs is sometimes done within the field when there is a temporal requirement to do so. Overall, reporting information remains in the background and there are no immediate implications for the organization or workers as long as reports are submitted within sensible time frames or when specifically required.

As result of delaying reporting tasks for later, there were various working hours reporting habits developed among workers in relate to physical spaces of reporting activities. The location of reports is very much affected by how adequate the allocated spaces are for human-technology interaction.

Maintainers were found to report either from their site offices or from home. Reporting from home was found to be more common among maintainers. Drivers have diverse ways to report; some start to report from site offices or their trucks and accomplish them later from other spaces. Some write information on paper in their trucks and fill reports later from other spaces. Construction drivers report either from their trucks, site office, or home. Maintenance drivers report from depots or from home. Maintainers are not reporting from the field. They usually do so from their site offices or depots at the end of the day, but also often from home. Reporting from home was found to be a very common practice by all workers.

Drivers were found to be the most consistent and "disciplined" when it comes to reporting. This consistency can be explained by the difficulty to remember large quantity of information necessary for the reports and due to lower degree of contextuality. Drivers are not interfered by the volatility of weather when in the field. They can utilize the phone for reporting from the vehicle while being idle. Drivers who participate in construction work had "dead" moments, when they are parked at the side of the construction site or while waiting for their cargo bed to be filled with material. This allows them to interact with their mobile phones for short periods of times.

Reporting habits by construction workers were not so different to those of maintenance workers.

Site offices and *permanent offices* are spaces where workers gather multiple times a day to have their coffee breaks and lunchtimes. This is where most face-to-face interactions and informal conversations are taking place. It is a very social place where music is played, coffee machines constantly drip and many crosswords puzzles are solved. The offices provide a safe haven from the rough conditions of the field and where workers can rest and fiddle with their privately-owned mobile phones. It is also where foremen visit to brief and check on workers. Site offices are usually more remote and due to their temporary stature are very basic. Permanent offices are situated in central locations, they are more equipped and tidy. There is a lot of movement in and out from offices during the breaks since they serve the entirety of teams, including subcontractors. In construction sites, there can be several site offices found on-site and they usually serve the same individuals. In larger construction sites, there is usually one office, serving as an administrative site. Inside sits the foreman at the side of a desktop computer. Workers are free to step in whenever they need to, to consult or to solve their issues. Furthermore, site offices also serve measurers who sit in front of desktop computers and feed information to the system that helps track progress of construction work.

Depots are spaces where workers need to visit in different frequencies. Depots are where information from reports and trucks is flowing to and where foremen monitor the operations. Depots are where vehicles are stored, from where maintenance operations are running and where team meetings and briefings are held. Some workers start and finish their workdays at the depots, this is where machines are taken and returned to.

Main offices are the headquarters, where planning, development and decision making missions are carried out and where official meetings of the different departments are held, sometimes with visiting business partners. This is where office workers are situated and carry out administrative work and managers monitor operations. Workers are required to visit the main office from time-to-time for training purposes, but not very often.

Physical spaces and the reporting process

Site offices, permanent offices and depots are where the reports are filled, usually at the end of workdays. It is less common for workers to report in the middle of day from sites during their breaks. Many things happen during the breaks that can interfere with the task of reporting, such as peers coming in and start to chit-chat, noise such as radio and the atmosphere is more social. Coffee breaks and lunches can be short, and workers generally like to utilize them to rest, discuss with colleagues, eat and drink and do other leisure activities. When breaks are over, it is usually time to head back to the field.

4.1.2 Virtual spaces at the workplace

ICTs were utilized in the field by all workers for diverse purposes, primarily to communicate with foremen and peers. In case 1, the mobile phone was the most prominent tool used in the field, through which maintainers were able to make calls to team members and upload media. In case 2, ad-hoc communication in the field was made mostly via radio control systems. Drivers were found to utilize mobile phones for other purposes. In case 3, team members were using radio control systems and two-way radios. There was lesser use of mobile phones visible in the field due to use of headsets and due to dynamics of construction work. Measurers were utilizing various types of gadgets for precise measuring tasks. The measuring work is recorded in their devices, it is automatically fed to servers in their computers and later used in different systems.

Mobile phones were used or present in all three cases to different extents. Workers normally carried two mobile phones; one work designated smart phone and one personal smart phone. The work designated mobile phone had various features and mobile applications, such as M-Reporting installed. Mobile phones were used for both synchronous and asynchronous interactions. Synchronous interactions were dominantly in use in urgent times, for example, to call foremen for guidance and for assistance. Asynchronous interactions were in regards to issues that can wait, for example, report of faults through WhatsApp, or reporting absence from work by SMS.

Maintainers reported that their mobile phones are constantly in their possession when in the field and are used to communicate with managers and peers for purposes such as of asking for support, call for equipment or reporting about issues. The duration of phone conversations varies based on the need. Mobile phones were also used to retrieve information in the field for the purpose of helping civilians or checking weather forecasts. Some communication with the foremen is made by sending *messages* or *e-mails*. E-mails messages mostly contain formal content with regards to the organization. Sometimes the same e-mails arrive multiple times from several senders.

Drivers had their work phones mounted to car phone holders or placed in compartments next to their driver seats or in their pockets. Mobile phones had many uses in and off the field. First, to provide automatic real-time location of trucks during snow removal operations. Second, during “dead” moments when parked at the sides of construction sites, or at site offices during breaks.

Mobile phones are used to communicate with foremen mostly when drivers are parked or outside of their vehicles. Drivers said they use mobile phones whenever they are required to report of issues related to their driving errands, or their schedules or to inquire about their work assignments. When on the move, drivers mostly utilize their radio controlled systems to chat with team members. Once in a while, mobile phones are used to help navigate to new sites.

Construction workers were less visibly relied on their mobile phones during the field study. They carried their mobile phones but used them less frequently when I was in the

field, possibly due to use of other devices such as two-way radios and assistive gear such as headsets. Over the years construction workers have started to utilize helmet-mount headsets with flexible microphones, which allow hands-free communication. However, I was informed that mobile phones are used quite often, for example, to communicate between measurers and ground teams. This communication is essential to troubleshoot errors in precision, where corrections are needed to be made. Mobile phones were used in site offices for personal purposes as well. Mobile phones were often used by foreman who constantly received calls from workers and managers. Foreman's interactions with mobile phones were carried out in the field or at the office.

WhatsApp is a messaging application through which maintainers collaborate with their team members. Maintainers said that WhatsApp is used to inform foremen about environmental issues by sending messages and uploading images of inspected locations. This was described by maintainers to be the easiest way to inform and receive feedback from foreman. WhatsApp groups are also used as a platform for all team members to communicate and co-operate between workers. It is a space where maintainers can exchange both work-related and unrelated information between them. Foremen can also provide information relevant to all team members in one or few WhatsApp groups.

Tablets were used in construction sites for satellite navigation purposes. Tablets serve construction ground teams or excavators operators to access project related information on screen. On ground, the tablet is placed on RTK poles and used in digging activities that require high accuracy. Excavators operators see map data through a screen placed in the driver's cabin but a tablet is preferable to have a better overview of the digging site. When tablets cannot be used due to space limitations inside excavators, workers use paper based maps. Tablets were also in use inside site offices for purposes such as information retrieval. They serve all team members working in the site but are not carried around because of their size.

Desktop computers were observed used in depots, permanent and temporary site offices for various applications. They are mainly used by foremen inside administrative offices within sites or depots to monitor the information that flows into the office. Foremen utilize many different applications for monitoring and analyzing information, and to correspond with other actors within the organization through e-mails. Measurers, whose work revolves around measuring construction tasks use computers several hours per week. They sit at the office at the side of large monitors and interact with several systems to record the progress of work at different sites. Desktop computers were used by maintainers in one permanent office to read daily e-mail briefs sent to workers by their foreman, or to plan ahead the schedule of the next workday.

Radio transceivers and *two-way radios* were used by drivers and construction workers in the field and on the move for two main purposes. First, to coordinate work of dispersed drivers; for instance, maintenance drivers utilized their radio control systems to indicate their positions and progress when mobile. Signals were sent to inform about

their current physical locations and activities. Second, to collaborate between ground teams and drivers on building sites; for instance, ground teams utilized two-way radios to regulate traffic of trucks when use of hand gestures was not viable. Radio transceivers and two-way radios signals offer short interactions due to their push-to-talk mechanisms. When workers are out in the field, they suffer from harsh conditions that limit their ability to asynchronously text message or synchronously talk via mobile phones. This contributes to higher dependency on radio controlled interactions, especially in construction work, where radio controlled means are extensively used.

Virtual spaces and the reporting process

Mobile phones were the most common devices for reporting amongst workers. Workers can potentially use devices of peers for reporting but almost never do so. The reporting process via the mobile phone is immediate. The submitted information is sent immediately and can be viewed by foremen on their desktop computers. More so, mobile phones were used to inform workers of their daily activities, which are later reported back by workers via M-Reporting.

Desktop computers were used by foremen for the purpose of approving reports of workers. Foremen can filter received reports by different categories such as types and dates of reports. They inspect and correct whether errors were found and approve. Once reports were approved they are sent forward and cannot be recovered. Analysis of other information received through M-Reporting is also carried out by foremen by using their desktop computers.

E-mails were used to some extent since some content from reports is sent directly to e-mail accounts. This was told to be a problem in cases where maintainers required feedback on their hazards reports from the field.

Tablet was used for reporting purposes in one site office. One worker reported from a tablet that was available for everyone. However, using shared devices was not common among workers since they require replacing user credentials each time upon access.

4.1.3 Social and mental spaces at the workplace

Home is a major source for well-being, where workers could rest and recharge their batteries after workhours and during weekends. This is perhaps the reason why some workers choose to carry out reporting tasks from home, as it allowed them to gain control over tasks that were underprioritized. Some interactions from home are inevitable due to the need to plan and organize work ahead or inform about absence from work.

The field is where workers have the least time to socialize and where they encounter busy workloads. Naturally, this is where they encounter various work-related demands and experience the highest levels of stress. Subsequently, workers positively perceive any aspects that can support them in completing their tasks and regaining control over their jobs. One positive aspect is the ability to cooperate and to collaborate with peers.

Working together to accomplish joint tasks is satisfying and rewarding. In contrast, work carried out individually provides a feeling of isolation and insecurity, such as in the case maintainers working individually in the city.

Mobile technology was largely perceived as positive, mainly to the ability to communicate and collaborate through it. First, the ability to call other workers and foremen from the field in times of need was indicated as very supportive. Second, virtual spaces such as WhatsApp and SMS were perceived as an efficient way to collaborate and communicate within teams. Third, mobile phones were regarded as productive as they enable to troubleshoot and coordinate assistance through phone calls. Many workers indicated that phone calls can solve issues of various calibers and of various levels of urgency. Lastly, mobile phones were mentioned to provide a sense of security when out alone in the field, as Maintainer 5 pointed out.

> *Maintainer 5:"But when we work a lot alone in the field it is some kind of a protection, because I can call emergency services or a friend if some risky situation comes, and it is really good".*

In all cases, mobile technology was generally perceived positively due to the ability to assist in work, to access information, to upload and send information and quickly receive feedback. Further, there was a collision between the small size and portability of the mobile phone, which was deemed as positive, and the small size of their screen, which reduces the visibility and restricts the use of the interface.

At the same time, some workers were expressing negative opinions towards mobile phones when used in the field. Such negative feelings arise from the need to spend valuable time to report activities, which can be similarly done later from the office. Several older workers were expressing insecurity about their ability to interact with mobile applications in general, and especially in the field.

In addition, obtrusive interactions, such as incoming calls, were perceived negatively and were reported to distract, interfere with work and potentially hinder carrying out assignments. The field is a space where workers need to carefully prioritize between work carried out in physical spaces and work carried out in virtual spaces. Work in the field has its own flow and mixing between spaces might cause mental overloads and overwhelm. As results, workers look to delay interactions whenever they can or look to interact with the least demanding tool.

Other stress factors were subjective to individuals and largely depended on their personal characters. However, generally, the occurrence of unexpected events and urgent tasks was indicated as a negative factor as they can lead to unexpected outcomes and clearly affect state of mind of people who take part in work efforts. Furthermore, work in the field impose harsh conditions and implicates tasks of all workers. Cold temperatures, pesky ice on roads, busy agendas, noise and other environmental factors inflict many difficulties for interactions with ICTs and affect the well-being and mental workloads.

Site and permanent offices' purpose was in contrast to that of the field. There was a distinct dichotomy between what occurs in the field and what occurs in the office sites. Work is restricted to the field and socializing is restricted to office and these two did not tend to mix. Site offices are social spaces, where people looked to have more time for chatter, to read magazines or to play with their mobile phones. There are constantly people going in and out, and a picture of hordes of trucks parked outside and workers and subcontractors having their lunches together inside.

Depots are where parties involved in maintenance work visit about two times a day to acquire vehicles and tools. This is where workers allocate some spare time to run last procedures to retrieve their borrowed equipment, to report information and to dress up for home. At the same time, such tasks can be carried out hurriedly, if not enough time was allocated due to high workloads. This could contribute to dissatisfaction, stress and to the delay of tasks such as reporting to workers' home.

Main offices are where most workers visit only few times and therefore they were not discussed much during the field study. Maintenance drivers are required to visit the depot to collect their vehicles and usually meet at the adjacent headquarters to grab coffee from the vending machine. They stayed at the main lobby outside the office complex, sipped coffee and chattered. Construction drivers reported to visit their main office once per month for the purpose of car inspection.

The main function of the headquarters for most workers is to go through training, for example, to learn about how to use new tools such as M-Reporting. Courses can last for several days where workers get to be away from their main duties and to socialize.

Social and mental spaces and the reporting process

Social dichotomy between reporting spaces exists between the field, site and permanent offices and depots. This dichotomy can explain reporting habits among workers to some extent. Field is a productive space and does not allow much opportunities for reporting due to spatial, temporal and contextual factors that were discussed earlier. Site offices are largely social spaces, which workers use to rest and to socialize. Such atmosphere is not perceived by workers to be suitable for the purpose of reporting. The differences between offices and depots are marginal, however, depots constitute a better environment since workers visit them at the beginning and end of workdays to acquire their machines. Depots are less social spaces because they are not visited as much during the days. They are where workers try to regain control over their jobs and are most likely to be used for reporting by whoever have the time or the self-discipline to sit and report at the end of workdays.

Reporting from home was defined as a casual experience by some. Home was described as a quiet place to report from in general. For most it was a space where they could regain control over their time and have concentration. Further, home is a space

where workers could have more autonomy, where there are no interruptions of the outer field environment or the social atmosphere of the office.

Reporting from home was not explicitly expressed by workers to be a negative experience. However, there were acknowledgements that the act of delaying reports to home environments is not ideal. So there is acknowledgment that home, as the main source for well-being, should not be interfered by work.

Maintainer 1: "I have developed a nasty habit of reporting every day at 10PM at night."

However, there were two extreme examples for approaches of workers towards working from home: on one hand, one maintainer driver was extremely resistant against reporting from home and said to systematically reserve 15 minutes at the end of each day to report from the depot. At home the work mobile phone is also shut down and only accessible via the personal mobile device. On the other hand, one subcontractor who works at a construction site said that postponing of reports to home is acceptable due to regular habits of doing paperwork from home.

The demand to provide working hour reports is once in every two weeks due to calculations of salaries. Therefore, according to foremen, if workers report once in every two weeks, it is acceptable. When workers are required to report earlier they are asked to do so in advance and then they comply and report.

The field study found that there are many reporting habits among participants due to the leniency of conventions. According to foremen, the reporting habits of workers can also be explained by a relative difficulty to report by some workers, possibly due to age and personalities but also due to the diversity of their tasks. From foremen point of view, for some workers the process of reporting is not as simple as others because the content of their reports often changes. When tasks are diverse, the reporting process takes more time due to longer and more and diverse information. As result, some workers choose to delay reports to when they can allocate enough time.

In addition, for some workers, reported information is really important due to various hourly rates, which affect salary income. Therefore, workers try to accurately select information and the reporting process requires more time. The reporting time takes the longest when workers report once in every two weeks. This was suggested by foremen as an explanation to why reporting is sometimes done from home.

Maintainer 3 (foreman): "Workers want to do it in peace, at home, because they can't focus here or something like that. I think they want their own peace. It's just a habit but there is some thinking behind it. They want to concentrate and do it meticulously."

Such habits were not found to cause any issues for foremen, since they report once in every two weeks, they usually do it very precisely.

Adapting to use mobile phones for work purposes required support from the close environment. Some workers were trained at their workplace by participating in courses,

or were taught by their foremen, but some required further assistance from their peers to demonstrate how to utilize new mobile phones and its applications. One worker reported having required assistance from a family member who assisted to download and install the M-Reporting application. For several workers, adapting required several weeks, while for others it required several days.

However, even workers who were less adaptive were able to recognize few, or even many advantages in utilizing the mobile phone for different work purposes.

Summary of the space analysis

To summarize, the space analysis has demonstrated that different physical and virtual spaces ultimately have their own purpose in the day-to-day work. A wrap-up of the findings is presented in Table 8, adapted from Vartiainen and Hyrkkänen (2010).

Home is a major source for well-being. Some reporting work is delayed to home where workers have more control and less distractions from the outer environment. Stress appears whenever there is a breakdown of the dichotomy between home and work, for example, when work related calls are received. Therefore, some workers knowingly choose to close their work phones and disconnect.

The field is the most productive space where most tasks are accomplished. In all three contexts work is physical and therefore is a source for fatigue and mental stress. The requirement to work from multiple physical locations within the field and to communicate from them results in fair share of uncertainty due to unexpected and urgent events. Use of virtual spaces within the field helps to regain control over challenging situations. At the same time, obtrusive interactions with mobile phones were perceived negatively because they often stop the flow of work. Work is usually prioritized over demands to report information. However, reporting tasks are carried out when possible, such as from inside of vehicles by drivers.

Site and permanent offices are a source for well-being during work hours as they allocate the space to rest, dine and have informal conversation with peers. A portion of work is taking place inside site offices in construction sites, where foremen use a desktop computer to process flowing data, to approve reports and to crunch numbers. Workers use face-to-face meetings with the foremen to receive guiding and solve problems.

The depot is visited frequently by maintenance workers and has two main functions, to meet with foremen and to have some control over the job. Depots are spaces where workers can sit at the end of the day and complete some final tasks, such as retrieving tools, discuss with foremen, and reporting with their mobile phones. The depot is a neutral space; there is less social interference and quite clear work divide. It is also protected from the outer environment and therefore offers the potential to serve as a space where interactions for reporting are carried out by higher number of workers.

The main offices did not have much significance for most workers since they visit them very seldomly to be updated on guidelines through training.

Physical / virtual spaces	Case 1 Maintainers	Case 2 Drivers	Case 3 Construction workers	Social / mental spaces	Case 1 Maintainers	Case 2 Drivers	Case 3 Construction workers
Home				*Site office*			
Purpose	Reporting hours Giving advice to workers (Foremen)	Reporting hours Stand-by during winter	Reporting hours Paperwork (subcontractors)	Purpose	Morning briefings Dining and coffee Dressing room	Morning briefings Dining and coffee Dressing room Reporting hours	Gathering tools Dining and coffee Morning briefings Dressing room Reporting hours
ICTs in use	Mobile phones and desktop computers	Mobile phones	Mobile phones Desktop computers	ICTs in use	Desktop computers	Mobile phones	Mobile phones Desktop computers
Well-being	Rehabilitation No distractions	Rehabilitation No distractions Shutting down work phones	Rehabilitation No distractions	Well-being	Rest Team support Leisure activities Visits by foremen	Rest Team support Leisure activities	Rest Team support Leisure activities Advice from foremen
Stress	Calls regarding work	Weather forecasts Volatility of hours Incoming calls from foremen	Calls regarding work	Stress	Cramped and crowded office space Multitasking	Cramped and crowded office space	Basic office space Processing data and multitasking Usability Calls from managers
Field				*Depot / Main office*			
Purpose	Maintenance work at changing locations Reporting hazards Operating tools	Maintenance rounds at changing locations / Construction related errands Reporting materials	Construction and measuring duties Operating machines	Purpose	Gathering tools Reporting hours	Collecting vehicles Reporting hours	Not relevant
					Courses and training	Courses and training Vehicle maintenance Coffee breaks	Courses and training
ICTs in use	Mobile phones	Mobile phones Two-way radios	Mobile phones Tablets and measuring devices	ICTs in use	Mobile phones	Mobile phones	Not relevant
					-	-	Mobile phones
Well-being	Job control Support from peers and foremen	Job control Collaboration with peers	Job control Collaboration with peers	Well-being	Face-to-face meetings with foremen Job control	Face-to-face meetings with foremen Job control	Not relevant
					Off field work duty	Chatting with peers	Off field work duty
Stress	Busy days Urgent tasks Incoming calls Guiding trainees Usability	Road traffic and pedestrians Urgent tasks Usability	Physicality of work Hazardous environments Errors Short-handedness Deadlines	Stress	Lack of job control	Lack of job control	Not relevant
					Adapting to new technology	-	-

Table 8. The purpose of using physical and virtual spaces for work, the mobile technology used in them and the perceived well-being and mental stress of workers.

4.2 The mobility dimensions and the three study cases

Next I present the differences between the cases explored during the field study. The cases will be analyzed by the three mobility dimensions presented by Kakihara and Sørensen (2002; 2004) as a framework.

4.2.1 Maintainers

The role of maintainers is comprised from a relatively defined set of responsibilities. Within their primary concern lies the task of taking care that environmental factors, the landscape and the surrounding physical environment do not pose a threat to pedestrians, cyclists and the general routine of urban life. Proper street maintenance also contributes to the attractiveness of the city and creates a more pleasant environment to live in. Therefore, the main objective is the general upkeep of infrastructures, pavements, streets and open spaces such as gardens and parks and their installed facilities. By being spatially mobile and on a constant lookout, maintainers reinsure that the environment can be reinstated back to order.

Spatiality of maintainers

Maintainers who were interviewed during the field study were dispersed in different strategic locations within the city center. Maintainers are assigned with their own territories and responsible for the continuing maintenance of its environment. Maintainers are positioned in permanent or temporary offices, which set up a base for their workday maintenance activities.

The role of maintainers has a routine element to it; maintainers are required to patrol and scan different routes during several days by foot. Along these routes maintainers must often pause and, when possible, perform maintenance activities or report about issues to their superiors. After completing their maintenance rounds, they continue to work somewhere else or return to their offices and depots to stay on alert for the remainder of the day.

The nature of their assignment differs between the seasons; during the summer, work is concentrated on gardening and landscaping tasks such as planting and trimming. These tasks require maintainers to stay at one location for several hours. After work is carried out, maintainers continue to do other tasks. In addition, there are other assignment that may involve collecting litter from trash bins or from the ground. These tasks require wandering back and forth within large open spaces, such as parks and gardens. Work during summer tend to be very busy and more dynamic than winter.

During the winter months, they are required to monitor the environment for the effects of climate, reporting it or taking immediate actions to prevent environmental risks. Therefore, maintenance work revolves around snow and ice and prevention of risks due to weather, such as slippery bicycle lanes or pavements. Such work is normally carried

out on the move. Few missions are carried out when mostly stationary, such as the maintenance of outdoor skating rinks.

Maintainers' spatiality can be categorized as local mobility, where there is a short distance movement within open spaces or around buildings. However, their spatiality extends further since maintainers may walk or be transported between different sites during one workday. In addition, some maintenance tasks require more walk for the retrieval of light tools from other locations in the vicinity, such as storage sheds or booths. Therefore, spatiality of maintainers extends to their very versatile selection of tools. Those are obtained and recovered depending on the job.

During the winter time, maintainers begin their day very early by patrolling their territories. This task sometimes concludes around noon and later, maintainers may head back to their offices, where they can be on stand-by or assist their peers. During the day there can be unexpected events that may require maintainers to deviate from their routines. This occurs when maintenance assistance is required elsewhere. Overall, some of the tasks are done together with fellow workers, but is often performed individually.

Mobile technology has contributed to a decrease in the spatial dimension of maintainers for two main reasons: first, the distances between dispersed maintainers were minimized due to the possibility to communicate at any given moment. One worker described it as follows:

> *Maintainer 5: "I can work on one side of Tammerkoski and ask help from someone that is on the other side."*

Furthermore, workers are informed of their tasks without the necessity to visit their depot. They are informed by foremen who send instructions in the mornings or during the workday through messages or e-mails.

Second, they send hazard reports that contain location-based information and upload images to foremen. This can be done by reporting but mostly done by sending an image through WhatsApp. Maintainers monitor the area to detect all sorts of issues that can be instantly fixed or may require that special tools will be delivered to them, while others are only notified to foremen for further care. In some cases workers inform foremen to spare work from others, for example, if some trash bins that are assigned to their peers were found clean. In such contexts, the mobile phone mediates and eliminates physical distances by a transaction of data that moves between two or more spatial locations. Such data consists of voice, images, location and text. However, there is no tracking system that notifies the whereabouts of everyone in the team.

For maintainers the mobile phone is a work tool that contributes to a better coordination of assignments, of delivery of tools and the support of team members. Further, maintainers get to know their day-to-day assignments by receiving messages or e-mails through their mobile phones. As result of using mobile phones they get to learn about the locations of their tasks more accurately and their spatiality has decreased.

Temporality of maintainers

Maintainers have organized schedules, which are based on prescribed work hours for the unit. The durations of their tasks change mainly due to seasonal factors, the weather forecast and occurrence of unexpected events.

The weather is important; based on forecast predictions workers can tell what kind of work should be expected. Extreme weather forecasts can affect the urgency of their tasks as there is a priority to perform certain tasks over others.

Furthermore, in urban environment, snow and ice are hazardous factors that need to be constantly controlled. The whole maintenance operation is experienced in dealing different types of weather scenarios according to its regulations. More so, maintainers are required to develop a sense of familiarity with their territory and know what kind of areas are prone to pose a threat due to weather changes.

Mobile technology has some negative affect on maintainers' ability to perform tasks. Some maintainers said that interactions with mobile phones hinder their work. Interactions were said to take valuable time since they cause work to cease. To answer the phone, workers have to stop, lower their tools, search their pockets and open their devices. This was indicated to be frustrating when workers are in a hurry. Moreover, mobile phones were said to disturb maintainers' concentration on tasks at hand when instructing part-time workers or when discussing with peers. One maintainer said that without mobile phones it could be possible to finish the tasks much faster.

Figure 8. Maintenance work in summer. Photo by: Jyrki Ristilä, Tampereen Infra.

Contextuality of maintainers

All maintainers said to carry two mobile devices when in the field; a designated work mobile phone and a private mobile phone placed inside their pockets. By utilizing work

phones maintainers can make and receive phone calls to foremen and peers. Privately-owned mobile phones are utilized for their private needs.

Most of the maintainers said carrying two devices is cumbersome because of the weight and space they occupy. It was said to be especially confusing when some try and remember in which pockets their phones were placed when receiving incoming calls.

Maintainer 1: "It's difficult, this I need to say. I always find the one and the other is lost."

Interactions with mobile phones were said to interfere the use of their day-to-day work tools. Two-handed interactions with mobile phones are interrupted due to operation of tools and machines. When an incoming call is received, it may be possible for maintainers to lower the light tools they are handling, however, it is not possible when larger machines, such as lawn mowers are operated. In such cases, maintainers delay the interactions due to the incapacity to operate machines or due to noise.

During winter time, the weather is a major disabler for mobile phone interactions. Maintainers said that due to extreme weather they often delay interactions or take cover somewhere indoors, inside of booths or vehicles. When an important incoming call is received, maintainers lower their tools on the ground, take off their protective gloves and try to sustain the cold. When rain pours they hide under a tree because interactions with moist touch screen is not feasible.

Another contextual factor that affects interactions is interdependency. This is when the presence of other people interferes with the capability to interact, or collaboration itself is interrupted by incoming calls. It is common during summertime when maintainers are required to lead part-time summer workers who accompany them. In such circumstances, workers prioritize interactions according to the urgency of incoming calls.

Generally, due to contextual factors, maintainers are somewhat relied on asynchronous interactions. By sending reports and messages through WhatsApp, they are able to continue and work on the move or utilize their tools. Calling by mobile phones is reserved for when something urgent happens.

4.2.2 Drivers

There were two types of drivers participating in the field study; drivers who support maintenance work and drivers who support construction work by carrying out errands.

Maintenance drivers play a major role in the objective of maintaining municipal infrastructure and therefore, carry out a variety of maintenance tasks throughout all year-round. By upkeeping the network of paved roads, bridges, road environments, road equipment and signs, they ensure the safety of all road users in the city and its surroundings. A safe and smooth transition of traffic of privately-owned cars and other municipal mobile services is a top concern. Another major role is ensuring that public

transportation functions without delays by clearing out obstacles from bus line routes and bus stop bays, and by rescuing stranded busses.

Construction drivers participate in tasks carried out on construction sites. Their work supports construction ground teams by running driving errands. The work of drivers is very much dependent on the type of machinery that they are certified to operate. Construction drivers were operating dump trucks and took part in tasks, such as loading cargo, shipping it to a dumping site and off-loading it. Maintenance drivers were carrying out various snow removal errands by using two types of trucks.

Figure 9. Trucks parked at a construction site office during lunchtime.

Spatiality of drivers

Both types of drivers hold a high degree of spatiality and they were the only workers in this study whose spatial mobility was the main option. They drive during most parts of the day and cover a relatively large terrain by operating their vehicles. The type of errands influences their degrees of spatiality. Their mobility can be best defined as *"mobility as work"*, referring to as the "*movement of people, goods or vehicles between places*" (Cohen, 2010). Such mobility is place and time dependent and allows little control over the course of the journey or its temporality (Cohen, 2010). The spatiality of construction drivers differs to that of their fellow maintainers, as their driving routes tend to be more "linear". In contrast, the spatiality of maintenance drivers was more fluid and required visiting more places and changing constantly due to work requirements.

Construction drivers begin their workday by driving off to an assigned construction site. Construction drivers that were interviewed were telling that the trucks they drove are owned by the organization but parked at their own homes during off hours.

While construction work is carried out on ground, drivers sit inside their cabins, parked close by on-site. The drivers move their trucks when being called to, usually via

a radio transceiver or by a hand gesture, then slowly steer the vehicle closer to the digging site and position the truck between pile of materials and loaders.

The voices that can be heard from the radio control belong to all team members working on ground and tuned to the same frequency. Drivers receive orders from ground team leaders and comply by steering their trucks accordingly. When cargo beds are being loaded, drivers sit still and wait until they are filled with material. After the cargo bed was filled, drivers are instructed to drive to an agreed dumping site. Upon arrival to the dumping site they may wait on a queue, or approach the vacant site and off-load the cargo.

The locations of dumping sites vary between days of work and construction sites. The length of routes to the dumping sites in two field visits were about 5-10 kilometers in length per direction. Construction drivers are required to drive to the dumping locations back and forth, multiple times a day. Their travel distance increases whenever they are required to head out to locations situated further away from construction sites towards dumping sites. As consequence of their high degree of spatiality, construction drivers are required to be in constant need to learn about new construction and dumping sites, and to learn how to navigate towards them and back.

Furthermore, construction drivers are required to maneuver within construction sites. This spatiality resembles to that of "*on-site movers*", which is work carried out by a back and forth movement in one area, like that of a farmers who harvest fields with tractors.

The spatial mobility of construction workers also applies to their cargo and the material they carry. The data in relation to where material and supplies go is important for the operation and being tracked for different organizational needs.

The mobility of equipment and material also applies to maintenance drivers and their vehicles. In road maintenance work, drivers are required to operate a higher number of heavy machineries to remove snow or pour salt and gravel. The information regarding quantities of poured salt and gravel is very important to the operation and is constantly being monitored by stationary technology installed in the truck. The information of where snow removal tasks were carried out is important and monitored usually by mobile technology.

Construction drivers indicated that sometimes they are required to drive their trucks to main offices for car inspection and other maintenance purposes. This was estimated to be done once per month. Visitations of maintenance drivers at their offices are more frequent, as they are required to collect and operate various vehicles.

The responsibilities of maintenance drivers are quite similar to those of maintainers who perform maintenance duties on ground. They are required to patrol and scout a territory for any possible road safety issues and report them in case of such occurrence. The areas that drivers are required to monitor are too large to be entirely covered during one day.

Maintainer drivers are also required to have an ultimate level of familiarity with their assigned territories. At the time of the field study they did not use any in-car navigation

system to show the way. Therefore, planning and carrying out maintenance related assignment falls under their responsibility. They carefully plan routes to avoid repeating the same street twice when on the move, for example, during snow removal duties. All drivers required to have an excellent familiarity with their routes. They relied on their memories and experiences driving local road networks as they handled their vehicles.

The ability to communicate and collaborate in the field has obviously made spatial mobility more fluid during the years due to the emergence of mobile phones and standard radio transceivers. The communication means available to drivers provide the possibility to transmit information over large distance. Therefore, maintenance drivers are no longer required to physically drive all the way back to their offices to inform of road conditions. Moreover, it also allows the whole organization to act immediately, as mobile technology has made it possible to refer available team members to act upon whenever needed. As result of this immediacy, the degree of spatiality of all tiers has decreased.

When drivers carry their mobile phones around they also became physically "free" from their trucks. They no longer need to wait for voice orders of foremen to hatch from in-car radio control systems. Mobile phones allow drivers to leave their trucks, go to their depots and still be available to be called-up when required.

Driver teams may also collaborate as they are on the move, or when being away from the trucks, which induces cooperation between peers. This allows a certain degree of independence and flexibility inside teams, as team members can coordinate the tasks among themselves and not only rely on orders from foremen.

By receiving real-time data of the locations of trucks it became possible to better coordinate the operation and reduce the complexity caused by the scatteration of drivers over the physical area. Foremen can call up maintenance drivers based on their location and send the nearest driver to events. For example, the rescue of a stranded bus or the clearance of an obstacle from the road requires quick response times.

The spatial mobility of maintenance drivers is more fluid and tends to alter as result of temporal factors such as seasonal changes and climate. Following the changes in their temporality there are also changes in their spatiality, e.g. in cases where drivers are required to carry out maintenance work someplace new.

Both maintenance and construction drivers hold an affiliation to specific areas. These areas are where they are required to work throughout the days. This spatial "ownership" is inherited from their foremen, who are responsible for operations carried out in different sections of the city. Therefore, maintenance drivers are usually responsible for the maintenance of their own territories, whereas construction drivers are assigned to a building site for various lengths of time. Construction drivers are assigned to sites as long as projects continue. The durations of projects can alter between several weeks and even years if they large scale projects, such as the construction of a whole new neighborhood.

The spatial mobility of both types of drivers can be defined as *local long-distance travelling*. However, there could be another interpretation for the spatial mobility of

construction drivers, as they themselves are not physically mobile. Despite they wander from one place to another when freed from their trucks, most of the distance they cover by handling a vehicle. Therefore, the spatial mobility of drivers is linked to that of their equipment as once they enter and operate their vehicles, they become physically mobile.

Temporality of drivers

There were various factors found to affect the temporality among drivers: seasonal changes are a major temporal factor that alters the type of tasks carried out by maintenance drivers. The nature of their tasks significantly differs between summer and winter seasons. In summertime, work tends to be more dynamic as the variety of tasks increases. In contrast, during the long winter months, their work is immensely affected by climate and precipitation and tends to be more rigid.

The most prominent weather factor that affects road conditions is the accumulation of snow and ice. Since the top priority year-round is given to the prevention of risk factors to road users and traffic, it subsequently leads to a sense of urgency in carrying out snow removal chores. As a rule of thumb, when substantial layers of snow or slippery ice accumulate, there is an immediate need to keep up the fluency of traffic and protect road users from hazards. Therefore, snow removal, salting and gravelling assignments are carried out during the small hours of nights or early mornings.

When drivers perform snow clearing duties, they are asked to activate real-time data that transmits the locations of their trucks to foremen in three different ways: one way is via a *stationary terminal*; a black-box located in the front cabin of larger snow-plough trucks. The trucks carry gravel and salt. The stationary terminal records and transmits the actions that were carried out by drivers. In order to pour material, the driver switches a lever connected to the terminal. The system records the data and sends it to the database together with the location of trucks.

The second way is via a mobile application installed in drivers' smartphones. Whenever drivers reach to the start of their snow removal routes they activate the application. Pressing the start button signifies about the commence of snow removal tasks, whereas pressing the stop button signifies about their completion.

The third way is via GPS trackers during the summer. The driver "locks" his or her information to a particular truck and location-based is transmitted to foremen.

By acquiring the location data of trucks, foremen can track where snow was cleared and salt and gravel were poured. In case of errors related to clearing of snow, foremen can act efficiently by summoning the nearest driver. The drivers themselves can also inform of their errors. For example, if they cleared snow but forgot to activate the GPS based application on time. By tracing the location of trucks the temporality factor is mobilizing and allows saving time. By receiving GPS data, foremen can coordinate the operation more flexibly.

Contextuality of drivers

Drivers are not exposed to environmental factors directly like workers who work in the outdoors. The task of steering a vehicle is done inside cabins, where drivers are protected from harsh weather conditions and are not required to wear protective gear.

The interaction with mobile phones can be seen as more feasible due to more comfortable circumstances inside the cabin, but as long as traffic permits it. Drivers have their work mobile phones attached to car phone holders, which makes the process of accepting incoming calls less cumbersome than for other workers. However, drivers are still required to divide their attention carefully. A major contextual setback is the need to constantly handle steering wheels and pay attention to different road conditions and traffic. Interactions with mobile phones and radio control may affect the ability to concentrate on working tasks. Therefore, the ability to simultaneously operate vehicles and communicate via mobile phones or radio transceivers is limited.

Another contextual issue in relation to mobile phone use inside the truck cabin is noise factor that originates from two sources: sound coming from engines and the work environment around the trucks. Two drivers were wearing earplugs to protect themselves from high decibels due to the running motor and friction noise derived from snow removal. A second source is sounds hatching from radio control systems, which may confuse and distract drivers. Radio controlled collaboration is done mainly inside the construction site, but sound of other radio conversations hatches all the time.

Due to contextual factors, only hands-free interaction is restricted due to inability to interact and drive at the same time. When drivers are in their trucks they communicate more through their radio transceivers. Phone calls are made when there are more pressing matters to communicate. Generally, phone conversations that require more elaboration are postponed to other places, for example, for resolving technical issues or issues with the reporting process. Handheld interactions through messages was more dominant when changes in schedule or related to absence from work need to be informed, but those can only be carried out in circumstances where the vehicle is parked or outside of it.

4.2.3 Construction workers

Construction workers, or “workmen” as they were widely referred to in the jargon used by other employees within the organization, are very much jacks of all trades: very skillful professionals who carry out physical yet very precise tasks.

Construction work relies heavily on cooperation inside the team. This cooperation is carried out mostly on ground but can extend outside into the virtual space when work of others is required. Within construction teams there are various roles:

- Ground workers, who carry out most of the manual tasks in the field using their bare hands or by utilizing lighter machines. They usually monitor the work of other professionals such as excavator operators and truck drivers.

- Excavator operators, who utilize heavy machines and carry out much of the digging tasks that otherwise could not be accomplished by hand. Their work requires precision quite often.
- Truck drivers, who carry out driving errands in and out the construction site.
- Measurers, who carry out precise work while utilizing various devices. They wander between different sites in one given territory but return to same office sites at the end of workdays. They perform measuring work largely individually. but their help is required where other work is carried out.
- Foremen, who partly monitor and partly administrate work at sites. They are middle managers with long previous experiences in construction work.

Spatiality in construction

The spatiality in construction work can be defined as "*mobility for work",* which refers to "*spatially dispersed and requiring mobility to be accomplished"* (Cohen, 2010). Construction workers were dispersed in various infrastructure construction sites all around the municipality, participated in the construction of roads and the renovation of municipal facilities such as parks and sport facilities. They perform work in the same area for months or even several years, depending on sizes of projects.

Size of construction sites depends on the scope of their projects. Some construction sites can be of relatively small scale, few hundreds of meters in dimension such as renovation of junctions. Others may stretch over vast terrains of several kilometers, where work such as the development of infrastructure of whole neighborhoods is carried out.

My field study with construction workers was conducted in two larger sites. The sites were in fact, two out of several others in the same area. As I was told, in each site there was a different group of workers that laid the foundations for streets where new housing and schools will later be built.

Construction professionals largely have similar levels of spatial mobility. Most can be considered to have relatively low degree of spatial mobility compared to other workers who were interviewed in the field study. The degrees of physical mobility is first and foremost determined by their skillsets, but also according to work requirements and other temporal factors. The lowest degree of spatial mobility is that of ground workers who carry out manual work on ground, and can be considered as fixed in most situations.

The work of measurers is different and heavily relied on their technological skills, which are often needed elsewhere, and therefore their spatiality extends further away. When measurers are needed elsewhere, they either walk or drive from one site to another during the same day. They often visit multiple sites during one given workday, but tend to return to the same site office at the end of the day. At the office they stay as long as it takes them to feed their measures to the system.

Workers who operate machines such as excavators tend to move like truck drivers mainly back and forth within the site, but can remain stationary when work ceases. The

spatial locations of excavator drivers are monitored through GPS by the measurers, if not switched off. I do not know how essential it is for the work but it can potentially improve the fluidity of work on ground, for example, when measurers would like to communicate with the closest excavator driver and troubleshoot errors.

Generally, construction workers' degree of spatial mobility is determined by the distance between digging sites and site offices. The distance ranges between dozens and hundreds of meters. The spatial mobility of builders increases every time they walk to their site offices and back, but nevertheless remains rather low.

Construction workers are required to walk from site to office multiple times a day. They arrive to their offices early in the mornings and then continue by foot to the whereabouts of work locations. Later they return to their offices for coffee breaks and lunchtimes, only to return to the site again later.

The resources that construction workers use are mobile as well. Some of the equipment utilized in the field is portable and carried by workers themselves from their offices to sites. Light machinery and tools such as tablets, RTK receivers and poles used for satellite navigation work, drillers and cutting discs are mobilized by hand or by vehicles and operated on sites according to the phase of work. Heavy machinery is mobilized by vehicles from one site to another, given it is a large construction area. In smaller construction areas, tools are located closer to digging sites and kept in temporary structures such as containers. Heavy duty tools such as levelling machines are lowered down by excavators to digging pits, where they are used to flatten surfaces. It is not unusual for workers to wait for equipment to arrive, considering that the operation requires an efficient coordination between ground teams and drivers.

Artifacts such as site plans were also found to be mobile within construction sites. Site plans are paper printed maps that include project related content marked on the maps. They are found inside site offices and serve workers in familiarizing themselves with the geographical settings of their projects.

Site plans become mobile when technology fails in its mission to support workers in the field. Excavator operators were found to carry laminated site plans in their cabins and utilize them to orient during the tasks. This occurs because screens located in excavators cannot be scaled properly and workers cannot navigate within the digging sites with their help. The maps on screens show a lot of information, which interferes workers in learning about the environment. Through tablets it is possible to view PDF versions of the same site maps but due to lack of space in excavators attaching tablets inside cabins is prevented and tablets are left in the office. Therefore, workers were found carrying printed versions of site maps in their excavators.

There are few spatial challenges in construction work. The prominent one is the physical structure of the environment, how to measure it and how the development of work affects the physical attribute of such environment. There is a constant need to keep track of work progress and document the changes to the environment due to work activities. Another challenge is that of professionally measuring the ground in various places and inform other team members of possible errors and their ramifications. Further, there is also a need to communicate the progress of work to stationary functionaries, who sit far away in the office. This information also needs to flow upstream towards officials who sit in the headquarters. Another challenge is how equipment and supplies are moved and delivered for work carried out in such environment.

Figure 10. Work in progress at a construction site.

Temporality in construction

Various elements were found to affect the progress of work: clock time, or workplace conventions dictate quite regular daily agendas for all construction workers. They set the ground for daily routines, which according to them workers come and go. Workers know when they should arrive at the sites during the mornings, when should they have their coffee breaks and lunchtimes and when they should head home at the evenings. Breaks are taken flexibly but workers normally try to act according to the clock. A social interpretation for time is expressed, for example, by workers having their breaks together with others, which happens in a rather consistent manner.

However, many different factors determine when work itself takes place. First, work is very interdependent on the progress and the whereabouts of team members who take part in the tasks. Some workers may hold certain skillset and therefore be required somewhere, but not available at given times.

Second, there is a large variety of tools used during different stages of work and mobilizing them may postpone some tasks. In addition, some tools can be used elsewhere and might not be available at every given moment. Same goes for vehicles and the people who operate these vehicles.

Third, schedules may be affected by the timing of shipments of materials or supplies to sites. There is a long list of materials and supplies used during work, for instance, pipes, gravel, sand, soil and more.

Fourth, construction work is a very precise labor; mistakes in work cannot be tolerated and therefore it can progress slower. On the contrast, work can be expedited due to urgent need to fix errors. If mistakes were detected, which is a rarity, they should be recovered and corrected. Nevertheless, delays in such cases are inevitable. Building site plans, diagrams and maps are essential to work, and they are paid special attention to during the stages. Therefore, it is required to wait for people with authority and plans to dictate what to do. When there is a hold, work is then improvised somewhere else.

Fifth, projects often proceed according to plans, however, unexpected events may occur very often during the construction process. When something unexpected occurs work is ceased and workers are required to rethink how to proceed. Delays in particular tasks are inevitable in cases where hard rocks are discovered and need to be denotated. In such cases work is continued elsewhere.

Finally, there are rather strict deadlines that determine when should projects be completed. Project time is an estimation of a sum of a total number of tasks that have separate deadlines. The progress of some tasks might be slower than expected whereas others may be quicker, which can subsequently offset possible delays. Delays in projects may implicate that work pace should be increased and as result, pressure levels are increased as well. However, I have been told that delays rarely occur and workers are almost never required to provide extra hours.

Furthermore, an important challenge in construction work is how to monitor and document the progress of work, since there are many factors that can change the schedule.

One factor that was found to affect this ability is the environment, season and weather changes. For example, it is not possible to carry out different types of works when heavy snow or rain pours. Further, when freshly poured snow covers the ground it interferes with visibility. It especially hinders work if workers are out in the field to continue work previously made by others. Moreover, some materials such as pipes could not be laid in the ground in very low temperatures, meaning work should be ceased and continue during a warmer day. In such cases work is moved somewhere else. Work is hardly ever entirely stopped because there are deadlines, costs of labor, subcontractors and equipment, but there is always the need to monitor, alter the tasks and inform workers what to do.

As a solution to track and monitor progress of construction work, workers utilize a cloud service that allows them to access real-time information from the field. In two

construction sites I saw ground workers and excavator operators occasionally utilize it to access data in regards to the digging site.

The use of the cloud service together with measuring tools was challenging in two cases. In the first case one construction worker tried to measure the height of a laid pipe by using an RTK pole and tablet that was placed on it. Synchronizing between the physical location of the pole and the coordinates on the screen took several minutes, all for the sake of accuracy. In the second case, an excavator operator used a screen to gain access to a digital map but demonstrated how it does not scale properly. Therefore, a paper map was carried in a compartment in the side of the cabin to help navigate accurately.

Figure 11. Measurer at the site office.

Contextuality in construction

The main contextual challenge in construction is how to access the data and how to perform precise and physical work by using technology in the field. Mobile technology has accommodated many new ways for construction workers to carry out their responsibilities with access to location-based data from the field. The effects of contextuality on construction work, however, are far greater than on other workers due to the higher dependency on accessing data to carry out tasks of high precision.

Contextuality affects construction work in several ways: first, during winter time, when there is not much daylight, poor visibility affects the ability to work and interact with technology and work tools on-site. Light emanating from projectors and vehicles helps to overcome poor visibility conditions to some extent. Work was not found to be delayed because of less sunlight.

Second, because their tasks are carried out in rustic conditions, it is expected that work of construction workers would share similar difficulties to the group of maintainers.

Their interactions with mobile technology are subsequently disabled by the same contextual factors. Weather and extreme low temperatures, protective gear such as gloves and helmets make interactions with mobile phones a challenging task.

To overcome contextual disablers such as cold and moist, construction workers can use touchscreen gloves that enable interactions with ICTs. This is essential for workers whose work requires accessing data more frequently, such as measurers. Measurers also carry out interactions inside the office sites sitting by the side of desktop computers, where they are protected from environmental factors.

To overcome contextual disablers such as noise, workers can choose to utilize headsets that allow them to communicate without the need of holding mobile phones in their hands. The headset is connected to their helmets and the protective pieces defending the ears. A microphone is attached to the edge of the helmet and can be lowered down to speak. The headsets allow workers to conduct synchronous conversations through the mobile phones with less interference. The headsets are usually used when workers are required to conduct longer conversations.

Shorter synchronous collaboration can be achieved by utilizing two-way radios. By using radio-controlled devices, it is possible to communicate with truck drivers, excavators and other ground workers dispersed in close-by sites, as long as they are tuned to the same radio frequency. Interactions made by two-way radios do not require workers to take off their helmets, which is less constraining.

However, when several people are communicating in relation to different issues at approximately the same time, radio controlled communication causes confusion. Therefore, not all workers like to use radio-controlled systems but rather prefer to utilize traditional methods, such as hand gestures. Use of two-way radios is also less favorable because of the weight and size of the device.

Furthermore, due to work dynamics of construction teams at the sites, communication between workers is often carried out without the assistance of technology. Construction workers are less physically dispersed in space, they hardly ever work alone and therefore are situated relatively close to each other. Hence, it is very common to communicate on ground through nonverbal cues, such as by shouting, whistling, honking or by signaling using hand gestures. However, nonverbal interaction can be challenging due to poor visibility in construction sites, due to large distances between workers and vehicle and machine operators, or due to the noise of machines.

Interdependency was also found to be a factor that reduces the possibilities for interactions with mobile phones. Construction workers, whose work is very interdependent cannot sustain many interruptions. This, however, may depend on how work progresses according to the timetable.

Table 9 demonstrates the mobilities of field workers in the cases explored during the field study. The table was adapted from Kakihara and Sørensen (2004).

	Spatiality	*Temporality*	*Contextuality*
Case 1: Maintainers	+	++	+
Case 2: Drivers	++	++	
Case 3: Construction		+	++

Table 9. Mobility of cases. '++' signify high degree and '+' signify moderate degree of mobility.

4.2.4 Summarizing the mobility dimensions and the reporting process

There were two main aspects in the requirement to reporting that relate to spatial mobility:

First, spatiality of workers affects the possibilities to interact and process reports. A higher degree of spatiality reduces the opportunities for interactions with mobile phones because workers spend more time to commute or to walk between places.

Maintenance drivers were the most physically mobile group among workers. They were constantly on the move or on the lookout or performed activities on the move. The requirement to complete work activities along driving routes did not leave much available time to interact for reporting purposes. However, interactions with mobile phones were possible for other purposes such as providing real-time location data of their activities through a mobile phone application. Such interactions were rather swift and did not require much attention, More so, they were deemed to be more important, whereas reporting was deemed as activity that can be delayed.

Maintenance workers were also spatially mobile and wandered between places very often. They were also found to be moving on-site or carrying out physical work for several hours at a time. Moving between spaces and carrying out physical work while moving occupies most of their time. Interactions with mobile phones for the purpose of reporting are not possible when there is spatial movement.

Construction workers were the least mobile among all workers but reporting was not seen as an option due to intense work. Construction workers were interacting with other means for purpose of accessing data.

Second, content of reports is determined by the spatiality of worker, e.g. where work is actually performed. By filling the physical locations in their reports workers assist the organization in gathering information about the whereabouts of work and the destinations of supplies and materials. As a result, the content of reports is changing according to their degrees of spatiality. The more places workers visit the higher the change in the content of reports. Drivers are the most susceptible to the requirement to report because they are essentially mobile for work. For example, when truck drivers carry cargo between places they are obligated to report it. If drivers visit more locations, they have to report more data in relation to their spatiality. As consequence, the more material they carry, the more they must memorize different type of variables for the reports.

Temporality was found to determine the frequency of reporting among workers in two main ways, due to organization conventions and due to the duration of composing a report. Since data about the outcomes of work is the main drive in the organization, there is an importance for information to flow upstream. Data flows initially from workers to foremen who approve reports, which later reach the back office. The process of reporting is ensured and monitored by foreman who is responsible to pass the conventions forward.

The results of the background questionnaire (see Table 11 on page 74) illustrate that eight out of twelve of the participants use M-Reporting for the purpose of actual reporting once a day. Three out of twelve indicated they report two to four times a day. One participant indicated to report between five and nine times a day.

The frequency of reports largely depends on their types; submission of working hour reports is limited to every couple of weeks. The demand to report working hours was found to have a lot of autonomy in regards to when, where and how reporting should be carried out. This was demonstrated in inconsistency between the cases. Submission of driver log reports is done daily due to the more frequent need to monitor and process costs of supplies, materials and subcontractors. Submission of safety detection reports was not compulsory due to the utilization of other available means and was found to be largely inconsistent between maintainers.

Between all workers, maintainers were found to have the least consistent reporting habits among participants. Reports by maintainers are sent either every day, once in every two days or more, or either on a once in a week basis. Reports are usually sent at the end of the workday, or later in the afternoon after they were delayed. The inconsistency in the reporting habits of maintainers is explained by utilizing M-Reporting only for the purpose of hour reporting, which lacks of clear conventions that dictate a prescribe time for reporting. Maintainers said that they report whenever work permits and indicated that there is usually not much time available during regular hours. In addition, other times, such as breaks, are mainly used to rest. Therefore, much of the reporting is delayed to the end of the day, or delayed to home when the clock is over.

> *Maintainer 1: "It would have been nice if I could somehow reserve time during the afternoon to come here and fill the hour reports, but usually I don't even have time to take my coffee breaks."*

Drivers were found to have more frequent reporting conventions, one driver said to report once a day, two out of four drivers said they report 2-4 times a day, and one driver said to report after every break, normally 5-9 times a day. Drivers said to finish their reporting quota usually every day and do not usually delay reports for the next day.

Drivers were found to have more consistency in reporting due to two main reasons: First, reporting by drivers is the most problematic reporting procedure because they are required to fill both driver logs and working hour logs. They are required to send information related to their cargo, material, destinations and more, which is used in a more urgent manner to calculate costs and to monitor supplies. For example, in the field

study one construction driver was asked by foreman to provide information about the cargo from earlier that day. This information was written on a separate note and was fetched at the time of filling the report.

Second, drivers were having more consistent reporting conventions because they cannot memorize the entirety of their information. They solve this in three ways; by entering data first and only later submitting, by accessing the application more often and report more often than other workers, or by manually writing down information on pieces of paper. Some drivers choose to maintain a diary, where they keep this information retrievable for reporting at later stages.

Furthermore, among drivers there was a phenomenon of delaying the submission of forms, where data was entered but not immediately sent. This occurs because drivers choose to edit reports before they send them. In driver logs they are required to enter data related to their driving errand, which they sometimes like to edit.

Construction workers were found to report similarly to maintainers but perhaps more consistently. They usually report once a day, at the end of the day or on the afternoon. Reporting was indicated to be carried out mostly from site offices or home as there are not many other adequate places.

The duration of composing a report subsequently determines the possibility to report within the field. The time required to compose reports differs between cases. Whilst most reporting processes take approximately 60 to 180 seconds to complete, the amount of data in the reports and the number of reports needed vary and could make the reporting process a more time consuming task. Drivers were the ones who testified to report the longest, between 10 and 15 minutes each day. Estimation of reporting durations of several workers ranged between 5-10 minutes per day. It also worth mentioning that for some workers the reporting process takes longer due to lower levels of technological proficiency. This may emphasize the difficulty in carrying out reporting missions from the field, where time is short, or from the office, where there are many distracting factors.

Contextuality can be attributed to the combined factors that were discussed above, especially to spatiality and duration of reporting. They together, impose many hardships on the ability to report from the field. The physical nature of work carried out by workers limits the opportunities to have lengthy two-handed interactions with devices.

The contextual factors were found to be diverse; cold climate, use of work tools and protective gear, handling of vehicles and others, all affect the capability to interact with mobile phones for the purpose of reporting. Further, factors such as noise, the presence of other people and interdependency were said to interfere with the ability to concentrate and have conversations through devices.

Table 10 shows the different mobility factors exemplified by the three mobile work cases explored during the field study. Some of the mobility factors are interrelated and associated with two or three mobile work cases.

<table>
<tr><th></th><th>Case 1:

Maintainers</th><th colspan="2">Case 2:
Maintenance drivers | Construction drivers</th><th>Case 3:

Construction workers</th></tr>
<tr><td rowspan="4">Spatiality</td><td>On-site movement</td><td>Vehicle obtainment</td><td colspan="2">On-site movement</td></tr>
<tr><td>Local mobility</td><td colspan="2">Long distance movement</td><td>Local mobility</td></tr>
<tr><td colspan="2">Data exchange</td><td>Vehicle maintenance</td><td>Data exchange and access to data</td></tr>
<tr><td colspan="4">Unexpected events
Seasonal changes</td></tr>
<tr><td rowspan="3">Temporality</td><td colspan="2">Snow work</td><td>Interactions for location data purpose</td><td>Reporting errand related data</td><td>Progress of others</td><td>Supplies
Deadlines</td></tr>
<tr><td colspan="6">Asynchronous interactions</td></tr>
<tr><td>Interactions with mobile phones (synchronous)</td><td colspan="4">Climate and environment</td><td>Interactions with cloud service</td></tr>
<tr><td rowspan="3">Contextuality</td><td>Interdependency</td><td colspan="2">Cabin space</td><td>Interdependency</td><td>Interdependency</td></tr>
<tr><td colspan="6">Handling of equipment and tools</td></tr>
<tr><td>Protective gear</td><td colspan="4">Noise factor</td><td>Protective gear</td></tr>
</table>

Table 10. Spatial, temporal and contextual factors in the field study.

Participant codename	**Experience of digital reporting**	**Frequency of use for information retrieval**	**Frequency of use for actual reporting**	**Location of reporting**	**Reporting features that were used in the past and present**				**Recent technical issues in reporting**
					Work hour log	Driver log	Safety detection	Number of total reporting features used	
Maintainer 1	4-5 years	Once a day	Once a day	Site and home	X		X	3	No
Maintainer 2	2-3 years	Once a week	Once a day	Site and home	X		X	4	No
Maintainer 3	4-5 years	Once a day	Once a day	Depot	X		X	6	No
Maintainer 4	2-3 years	Once a day	Once a day	Site and home	X		X	4	No
Maintainer 5	4-5 years	Less than once a day	Once a day	Site and home	X		X	2	No
Driver 1	4-5 years	5-9 times a day	5-9 times a day	Site, truck		X		1	No
Driver 2	4-5 years	Once a day	Once a day	Depot	X	X	X	4	No
Driver 3	2-3 years	Less than once a day	2-4 times a day	Depot and home	X	X		2	No
Driver 4	4-5 years	Less than once a day	2-4 times a day	Truck and home	X	X		2	No
Construction 1	4-5 years	Once a week	Once a day	Site and home	X		X	4	No
Construction 2	4-5 years	2-4 times a day	2-4 times a day	Site		X		5	No
Construction 3	2-3 years	Less than once a day	Once a day	Site and home				1	No

Table 11. Reporting habits through M-Reporting by participants.

4.3 Usability through the usability images

There were few usability issues with the utilization of information technology in general that workers found to interfere their work in the past and in the present. Issues in the past were mainly due to technical reliability of old equipment, such as mobile phones limited in capacity and lack of memory space. It is important to note that current equipment (used by workers in the field study) was regarded as reliable. Other issues were brought up, such as lack of feedback while utilizing mobile applications and small size of touchscreens. In some cases where usability of general systems and equipment failed, it led to paradoxical situations where workers did not use it but resorted to alternative ways to accomplish their tasks.

In the following section I look at the usability of mobile and information technology and the M-Reporting system through each of the six usability images, introduced by Hertzum (2010) in Subsection 2.2.4. This will allow to focus on one aspect of use at a time and examine the different characteristics and how they affect the usability from one perspective at a time.

The evaluation through the usability images has located several usability issues in the reporting process as result of the use of M-Reporting. Most of the usability issues were found due to the situatedness and organizational perspectives of use and in turn contributed to challenges in carrying out reporting tasks in the field.

Universal usability

M-Reporting is intended to be used mainly by field workers but is used by other workers who carry out work in office settings as well. The M-Reporting interface is, in principle, nearly the same for all workers in the organization and therefore the reporting process itself is similar for all.

Still, some of the configurations differ between workers to prevent novice workers from making errors. For example, not all workers are “exposed” to the same elements in the interface. Nevertheless, the reporting process largely remains the same and offers one approach to tackle the process of entering data.

However, usability issues can arise due to user diversity. Interactions by older workers were evidently slower than younger despite filling similar content in the reports. As a result, it led to workers to use the system differently than more competent technology users, resulting in some workers postponing interactions for the purpose of reporting to the end of workdays and to their homes.

Slow interactions were reported largely due to the schematic form-based interface that requires to drill-down and scroll through large amount of data on relatively small screens. The process of retrieving information was reported to be time and attention

consuming. This was mainly due to what was described as unintuitive enough interface to interact in the field. Some workers would like to have more freedom in selecting information over somewhat limiting form-like structure of the interface.

The schematic interface was indicated to be problematic due to two main reasons; first, interactions with it are relatively long and second, recovering from errors is hard.

Observations of interactions supported this notion. Measuring of durations of interactions varied between workers and the reporting features. Reporting working hour logs were relatively short, mostly between 60 and 180 seconds but this could be relayed to the repetitiveness of the tasks. While some workers were grown accustomed to the report process and demonstrated to interact very fluently, not all workers had the competence to develop such familiarity.

The occurrence of errors during the reporting process was not common during the observations. In only one out of the seven cases that workers were observed and recorded reporting there was an error in data entry. However, the erroneous report was difficult to recover due to lack of clear signifiers and it resulted in a much longer interaction.

A knowledge gap can be considered as an issue due to organizational practices of training their employees. Training of employees was found to be different between cases due to different practices within their departments. Maintainers were entitled to a course, whereas drivers reported to receive demonstrations from their foremen. Maintainers have also reported to receive support from their foremen and drivers were more likely required to learn by experience.

M-Reporting is usable across a variety of systems and accessible from mobile phones, desktop computers and tablets, which potentially could be used to serve the diversity of users. Therefore, the technology variety cannot be considered as an issue in this study.

Situational usability

The main situational usability issues that interfered with the reporting process were due to how the system considers different spatial, temporal and contextual factors to allow workers to report from the field. Essentially, reporting is carried out similarly regardless of the variety between work contexts. The reporting task should better consider the differences between contexts of mobile work and their spatial, temporal and contextual divides.

Spatiality: there were different degrees of spatial mobility between the cases, which M-Reporting does not address how they affect the ability to report. On one hand there were highly spatial mobile workers that were affected by high level of uncertainty which extends to the reporting process, and on the other hand, workers who were locally

mobile and had more control over their reporting content. Both type of users were using the same solution. For highly mobile workers, the retrieval of information is difficult, due to the process of selecting physical locations from the interface.

Driver 2: "Searching for information is easy, but retrieving it is difficult."

Physical locations are assigned to names of foremen and workers need to get familiarized with responsibilities of various foremen to successfully accomplish reports. Therefore, highly spatial mobile workers have to cope with more challenging demands when reporting.

Temporality: not all workers can equally respond to the temporal demands of the reporting process. It was found to be relatively lengthy and required workers to prioritize work tasks and breaks over reporting. The ideal way to report through M-Reporting is carried out in sequences, after each break. For this to happen, workers would need to have self-discipline and dedication, but more so, they would need to vacate separate times to have multiple reporting sessions each day. The alternative is to report altogether at the end of the day, however, for some workers it is very challenging due to the need to memorize many details. In contrast, to vacate separate times a day for reporting purposes is just as much challenging due to time constraints and contextual factors in manual and mobile labor.

Contextuality: while some workers were susceptible to the effects of harsh weather conditions, others were not. Similarly, while some workers operated tools and vehicles, some had their hands free. Overall, the reporting process carried out in the same manner in all context of work was not flexible enough to overcome most of the contextual disablers explored in this research.

Furthermore, Table 12 reveals the number of taps required to compose two types of reports, working hour logs and driver logs. The findings were collected from the field observations among seven participants. The table shows that the reporting process requires a relatively large amount of single-touch gestures to compose reports. Such findings may very well emphasize the complexity of the reporting process under the many contextual limitations imposed on field workers.

Table 12 shows that more taps were required to report working hours than to report driver logs due to the requirement to enter more data. The lowest number of taps was recorded by Driver 3 and can be attributed to a lower requirement to enter data in road maintenance tasks carried out during the winter.

In cases where participants were observed composing multiple reports, a decrease in the number of taps required for their second and third reports was recorded. This may be explained by several reasons; first, initial reports usually required changing content such as the area and type of work in the beginning of the day. Second, due to entering more information such as an additional working hours for work that was carried out

early in the morning. Third, the later reports included the same information entered in previous reports. The number of taps required for later reports was significantly reduced when the system automatically restores the content of previously submitted reports. Lastly, entering data in later reports was more repetitive and therefore shorter.

Participant codename	*Number of taps required to compose a working hour log*	*Number of taps required to compose a driver log*
Driver 1	-	27
Driver 3	29 (4), 22 (5)	23 (1), 17 (2), 12 (3)
Driver 4	-	32
Maintainer 1	47 (1), 24 (2), 21 (3)	-
Maintainer 4	41	-
Maintainer 5	50 (1), 26 (2)	-
Construction 1	36	-

Table 12. Number of taps required to compose reports by field workers. Some participants composed more than one report during the observations. The order of their reports is shown in brackets.

Other situational usability issues were in relation to reliability of equipment that interfered with the interactions in the field:

Old mobile phones were reported to interfere with the possibility to fluidly interact with the mobile application installed on them. For example, maintenance drivers are required to interact with a mobile application to activate real-time location data, but the application lagged and hindered the interaction. This happened while parking the vehicle at the side of the street before and after snow removal duties. Moreover, activation of real-time location data did not provide any feedback to driver and driver could not tell if the location data of the truck was transmitted.

Furthermore, foremen were also required to juggle between several systems, memorize various passwords, crunch numbers and produce and edit reports, by working with relatively basic equipment.

Poor representation or lack of representation of geographical areas was reported in construction work and road maintenance to hinder use of technology and work in general. First, navigation in a construction site by an excavator operator could not be assisted by using a cloud service map due to its inability to scale properly. As result, the excavator operator was using a laminated printed map that was carried in his cabin. The map was used to navigate, whereas geolocational information from the cloud service was only used to access information. However, the use of the same cloud service by measurers within construction sites was reported to be efficient.

Second, maintenance drivers were navigating through the snowy roads without any navigation means and by memorizing their entire snow removal routes. They may benefit from seeing their own and their peers real-time physical locations to learn about where snow was already ploughed. No such system is used at the moment as part of the road maintenance missions in the organization to the best of my knowledge.

Perceived usability

The experiences of using M-reporting were subjective and differed between workers. The system was perceived by positive to negative feelings, and at times by indifference.

Age and gender factors had slight effect on how workers perceived the ease of use. A higher number of negative comments was received by the maintainers of Case 1 in regards to how problematic the daily use of the application was for them. Younger workers gave less indication of usability issues and had less negative opinions about the reporting process in general. Also some expectations of having changes in the interface were voiced.

Perceived usability can be largely understood by how M-Reporting was adapted by workers versus the traditional methods that were used prior to it.

The demand to use the mobile phone for the purpose of reporting was received with some resistance. Older workers were the ones who expressed to have the most difficulty to adapt to the idea of digital reporting. Foreman suggested that the differences in adaptation levels were as result of cultural and technological gap between generations of workers. That adaptation experiences were different between older people who had lesser previous experience of using computers and mobile phones and young people who were automatically able to adapt due to higher levels of competence using technology. Foreman said that older workers were possibly too afraid, insecure and uninterested to learn how to report. Younger workers were said to have little issue with the process of learning.

Most workers went through special training in order to learn the principles of digital reporting. However, adapting to the reporting process sometimes required further support from the close environment and was catalyzed by help from peers, managers and even family members. There were still few workers who found the digital process to be difficult, but most workers were adapted to it and perceived it as useful.

Positive perceptions towards the usefulness of the reporting process referred to M-Reporting being a massive improvement from the previous reporting method. The digital way to report was perceived as more useful than the paper sheets unanimously.

Maintainer 1: "Surely using it is easy and comfortable and even easier than using the papers."

The main advantages of digital reporting were attributed to the reduction of time and to the ability to send reports right away. If someone forgets to report he or she can immediately fill it and send, while paper sheets could be delivered only in the next face-to-face meetings with managers. Paper sheets were said to be long and required more time to be manually filled and could potentially get lost. However, some workers said that previously they could ask for copies of paper sheets and therefore document their working hours better. In the digital way, the history of working hour reports is saved

within the application only for two months and then deleted. It was also said by some that accessing the history of reports through M-Reporting is cumbersome because it requires scrolling through lots of information.

The only workers who do still use manual paper sheets to report their working hours are summer trainees who, according to participants, would like to use digital reports as well. This was confirmed by the maintainers foreman who told that many of the young summer workers wanted to digitally report by themselves.

Overall, M-Reporting was opted as a much better alternative by everyone who were interviewed when comparing it to paper reports. This contributes to better perception of the system whenever they were asked to explain their general experiences.

Hedonic usability

While the M-Reporting system was perceived to be useful, it was not perceived as pleasurable. The use of the system was perceived strictly as a work tool that is mandatory to the organization and necessary to receive salary wage. The use of the system was not indicated to evoke any feelings of happiness or pleasure, but rather a bureaucratic tool that serves the organization in collecting data. However, the system was not indicated to evoke any clear negative experiences to workers either.

Aspects in the reporting process that could be interpret as negative are in relation to the uncertainty and ambiguity of some of the reporting task, mainly due to how well workers interpret the content as meaningful.

Workers have indicated that they try to comply with workplace demands and enter accurate data into their reports. They understand that information bears meaning to the organization and constantly try to interpret this meaning. However, the demand to report creates some feelings of uncertainty due to lack of control over the content they are required to select.

First, such uncertainty can arise from the taxonomy of content, as some categories may not exactly reflect the tasks workers carry out. Furthermore, categories were said to be too general, inaccurate, too ambiguous and even outdated. As result, workers may try to interpret the content of reports and select the least ambiguous option in relate to their work assignments.

Second, such uncertainty can be caused due to large quantities of information that is available to be selected. In some cases workers select wrong information due to the long process of sorting out the data.

Third, workers can select only one task when filling the reports, but in reality they carry out multiple assignments. As result, they ponder which task is the most appropriate to select.

Organizational usability

Organizational usability considers how well the usability of the M-Reporting system and mobile technology in general answers the requirement to work and collaborate within the organization setting. Organizational usability asks that a system will be integrated into the structure and the work practices of the workplace, where it serves a part in the collaborative process carried out by users who hold different roles and responsibilities. (Hertzum, 2010)

The main organizational usability issue was due to coordination of work activities. In maintenance operation, where work activities are carried out alternately together and individually, information is reported individually without contributing to the ongoing administration of maintenance task-fulfillments. The data from working hour reports is processed by foremen merely for the registration of work hours. At the current state, monitoring task-fulfillments is carried out manually and separately from the reporting process, yet workers are required to provide precise information about the daily outcomes of their work. As a result, foremen and maintainers exchange information about the status of work activities through several other channels.

In the case of construction work, where work is collaborative, the reporting process does not consider that teamwork report activities are ultimately co-dependent. At the current situation, reporting is done individually and concludes in an abundance of data that does not correlate with reports of other team members. For example, information from the work of an excavator operator that digs out material is not matched to that of a dump truck driver that ships the same material elsewhere. There is room to "harmonize" variables of supplies and other material based on joint team activities.

Other organizational usability issues that are associated to the coordination of individual tasks: first, the reporting process was not found to consider that some workers have other skills and therefore might use different tools as part of their jobs. For example, workers who work with special equipment are required to submit additional reports, which multiply the time required for reporting.

Second, the process of reporting driver logs does not match between type of equipment and type of supplies. For example, selecting the type of vehicle does not automatically triggers a compatible type of cargo or its capacity metrics.

Third, workers might have many goals in relation to their activities, whereas with one report it is possible to serve only one specific goal. For example, the collaboration between workers and foremen in the maintenance operation might also require inquiring and alerting about real-time task fulfillments at various points during the day. The system should allocate means to achieve as many goals in fewer interactions.

Furthermore, the system was found to not accommodate enough awareness of the evolving status of handling hazards reports. First, workers who use the safety detection

feature to send hazard reports do not receive feedback from foremen because the reports are sent to their e-mail accounts. This means that once reports were sent, workers could not know if hazards were eliminated. Second, the locations of safety detection reports were automatically logged from their locations and workers did not know how or were incapable to edit their locations. As result, workers were required to send reports only from the hazardous location itself, which limited their ability to carry on moving or prevented them to send reports later from indoor spaces.

At the moment, the process of reporting challenges both workers and foremen due to the requirements to fill and process content of many individual reports. The main implication for this is that foremen are overwhelmed by data and required to process a large mass of content, approve it or report it forward.

On top of that, a relatively high number of tasks are represented in the interface by assignment of values and names. This yields a large pool of data that is needed to process by functionaries, middle managers and workers alike. Processing this information was found to be slow and to create errors. This was indicated to increase mental workloads of foremen, whose responsibility is to fix issues in relation to erroneous reports.

At the same time, erroneous reporting was found to affect workers as well. This occurs when content of selective data contains only numeric values. It requires workers to carry a separated paper sheet with names of places to interpret the numeric values of the content upon data entry. Workers who do not have such solution usually call their foremen or just select arbitrary information. This was defined by one maintenance driver as a "*lottery system*".

Moreover, the system was not found to consider that tasks are changeable and require an additional control over data entry content. At the moment, there is no ability to construct blocks of information to allow workers to easily sort their own content. Reports can be filled by editing a template that contains the last entry data, or use content of previously sent reports, which shown to reduce the number of taps required to compose reports. Nevertheless, the possibility to harness or construct content based on workers' work routines is not yet used to its full potential.

Finally, before holidays workers are required to send reports two weeks in advance. This creates a paradox where they have to speculate what work it will be. It causes some workers to think that the content of reports is not that meaningful after all.

> *Maintainer 1: "It came to my mind that why can't I just punch-in the eight hours that I've been working and why do I need to specify what I'm doing when it doesn't matter? Do work that matters [laughing]!"*

Cultural usability

Cultural usability considers how mobile technology addresses the various cultural backgrounds of mobile workers. Such viewpoint suggests that the usability of systems should be evaluated based on how the user interface considers elements such as graphics, language, object formatting, colors and layout. (Hertzum, 2010)

In this study, the cultural backgrounds of workers were homogenous. All of the workers were locals. Many of them were born and raised in the same municipality and Finnish was their mother tongue. There was no representation for other cultural groups besides Finns in the field study. Therefore, the elements of the M-Reporting's interface can be specific to one particular cultural setting and may still perceived as usable.

Nordic cultures are characterized by their low power distance and femininity according to Hofstede's cultural dimensions (Hofstede et al., 2010). The use of M-Reporting, on the contrast, can be characterized as competitive and goal orientated. The demand to report serves the purpose of promoting efficiency by mandating workers to generate data and document their work practices, which was indicate to have negative effects on workers' well-being.

The characteristics of the M-Reporting system can be categorized as masculine. The way it works is directed at male dominant blue-collar personnel and befits the characteristics of blue-collar organizational culture and its social roles to some extent. In masculine cultures it is expected that designs will lean towards models of command and control rather than providing for exchange and support (Hofstede et al., 2010). This approach, on one hand, was not found to affect how male workers perceived their adaptation to the system. On the other hand, the process was mostly independent and only adequately supported. At the same time, such approach disregards female dominant teams and impede the adaptation process by female workers. The field study found that maintainers, which in this study were all females, required more support from their close environments compared to males in adapting to the system and encountered more challenges in using the system.

The way M-Reporting is used within the enterprise can also be characterized as authoritarian. The system does not allow workers to correct errors after sending reports by themselves. Once reports were sent they are unrecoverable and cannot be corrected. Workers are also unable to edit or duplicate reports to correct sent erroneous reports. The same issue applies to foremen who approve erroneous reports. They cannot retrieve them once they were sent forward. The errors can only be fixed by contacting the next manager in line. This issue was regarded by most workers as very troubling because it forces workers to call or approach their foremen and might stall their work. Workers and foremen have indicated they would like to have more authority over actions to recover from errors.

5. Discussion and future recommendations

5.1 Discussing the key findings

The circumstances under which the use of mobile phones by mobile workers is carried out are diverse. Workers were all found to use their work designated mobile phones to carry out different missions and did so as much as their work surrounding and job allowed them to do. Demands to utilize ICTs, although different between workers, were countered with the best of their ability to improvise under the physical conditions and under their job requirements.

Mobile technology use circumstances in mobile work

ICTs were found to have many positive virtues and to assist workers in carrying out tasks such as to communicate, to access data and to troubleshoot errors. They were also reported to provide a feeling of security when some workers were out in the field. At the same time, interactions with mobile phones in the field were indicated to hinder workers in carrying out their duties.

In many regards, the mobile phone is like a double-edged sword, as its use is beneficial when it comes to aid workers in times of need, but perceived negatively when their sense of control over it is lost. Mobile phone use was found to provide access anytime and anywhere, but at the same time, it remains challenging mainly due to the spatial, temporal and contextual dimensions of the job.

Workplace demands to utilize ICTs to mediate communication and to report information, collaborate and communicate are met by workers developing various ICTs use practices to cope with their physical work environment and to successfully carry out their tasks. Such practices were embodied through improvisation with their resources and within their allocated physical and virtual spaces, as was demonstrated in the spaces analysis.

The exploration of the utilization of mobile phones for the purpose of reporting has shown that workers develop different types of reporting habits that subsequently determine when, where and how they complete their reporting tasks.

The demand to report was found to vary between workers but was relatively high for drivers who were required to send many reports during one workday. The demands to report different kinds of information forced workers to prioritize between their actual work and their reporting tasks, which subsequently compelled workers to improvise in order to meet with the demands. Furthermore, workers were found to have a relatively high degree of control over their reporting assignments. The absence of incisive workplace conventions in regards to when, where and how to report has granted

workers with the autonomy to report at their most convenient times, places and manners.

Limitations in the field

The exploration in the field have concluded in finding the main limitations that were found to affect the use of mobile and information technology in blue-collar mobile work carried out in the field. Those were summarized according to the three mobility dimensions:

Spatiality was found to mainly affect the ability to have control over interactions due to high degree of physical mobility. Busy work days and the need to move between places eliminate many opportunities to interact with devices and contribute to higher levels of uncertainty. All workers were dependent on mobile technology to access or to send data regarding their locations. Mobile phones were found to reduce spatial distance due to the ability to receive information related to their tasks. In road maintenance, real-time location data from trucks is essential to monitor and to coordinate the work of drivers. In construction sites, access to geolocational information is essential to work carried out on ground.

Temporality was found to heavily affect the ability to communicate during work due to time constraints and therefore workers relied more on asynchronous interactions. Work schedule and the need for interactions are affected by many unexpected events that can occur during workdays.

Contextuality was found to mainly affect the ability to interact with devices due to physical nature of work. Aspects such as operation of tools and vehicles, low temperatures, poor visibility, protective gear and noise, negatively affect the situatedness of interactions with devices and the ability to concentrate while interacting.

Ultimately, there were various kinds of mobility between the work contexts as the nature of their tasks and their reporting need differ. The reporting process via M-Reporting is carried out the same regardless of the limitations and the special requirements workers have. The reporting process should better consider the particularities of each profession and offer different reporting experiences to match the needs of each worker, the particular goals and the responsibilities that each profession carries.

The usability evaluation through the images of usability helped to gain a better view of the use of ICTs and the M-Reporting system. Usability issues were found to affect the ability to execute different work-related tasks. The organization demands from workers to produce the outcomes of their work is reflected in creating a user interface that requires workers to enter many different variables, drilling-down through information, interpreting ambiguous categories, scrolling and tapping the screen many

times to comply with the demand. The digital form-based filling style is lengthy, requires many taps and stands in contrast to the contextual limitations arisen in the field. Moreover, the form based interface is offered similarly to all workers regardless of the circumstances of their professions.

Organizational and situational usability were the most dominant images of usability. They were found to reduce the effectivity of the system in accomplishing the reporting goals of workers in the field, where resources such as time and attention are limited. Other usability issues were due to malfunctions in old devices that interfered with the ability to run installed application properly. Some usability issues caused technology to fail and were replaced by manual means and by micro-mobility of objects.

5.2 Summary of the study context

The research has shown that the demand to report is answered with the development of various reporting habits. The mandated use of M-Reporting is manifested through workplace demands to report working hours and generate different types of data that serves the organization in monitoring its operation. The demand varies between contexts of work and was found to be relatively challenging for drivers. Reporting was found as an activity that occurs in the background, as it was almost never carried out from the field. The majority of workers were found to delay interactions for the purpose of reports to when and where they could vacate enough time and attention. The circumstances in the different physical spaces determine the possibility to interact for reporting purposes. The field was found to be a space that is reserved to manual work and offered very little opportunities for workers to report out in the open. Site offices were rather social spaces and did not offer the right atmosphere to issue reports.

The reporting process was found to be affected by various limiting factors that were summarized into three interrelated mobility aspects exemplified in the three explored contexts of works.

Spatiality was found to influence the ability to report due to physical movement: movement by vehicle obstructs interactions due to operation of vehicles and movement by foot offers little opportunity to have heads-down interactions. It also determines the content of reports and increases the complexity of the process of reporting by for example, memorizing more information at once, calculate cargo due to higher spatial movement and so forth.

Temporality was found to affect the ability to report due to pressing work schedules. The reporting process was found to be relatively time consuming due to the durations and the frequency of reports and workers chose to delay it. Furthermore, the lack of organizational conventions that set unequivocal terms to when, where and how reports

should be issued implicated inconsistent reporting habits. Worker have indicated to improvise due to time constraints and to delay some interactions with M-Reporting to their homes.

Contextuality was found to influence the possibility to report from the field due to situational limitations. Contextual factors such as cold climate, protective gear, driving vehicles, handling work tools and others were found to limit the possibility to have two-handed interactions with devices. Other contextual factors such as noise, presence of other people and interdependency negatively affect the ability to concentrate on the task of reporting.

Reporting activities via M-Reporting were executed mostly from offices and depots. Further, an overwhelming majority of workers were found to delay some of their reporting assignments and carry them out from home. Other types of reports, such as safety detection were very rarely used by workers due to usability issues and better allocated alternatives that served the same purpose of reporting events form the field.

5.3 Design oriented recommendations

Based on the field study, design-oriented recommendations for the service provider were collected. The recommendations aim at having a more fluid and flexible reporting process that will help overcome spatial, temporal and contextual limitations. The recommendations aim at reducing the number of reports and therefore, decreasing the time spent on creating and analyzing them by workers and foremen.

Main challenges in maintenance and construction work

The field study began by exploring three cases of mobile work with the aim to locate the main challenges that generally affect the utilization of mobile phones for the purpose of reporting information in the field. In order to draw recommendations six main challenges were first identified. The challenges are divided into two main lines of work carried out by workers; maintenance and construction labor. These challenges are summarized by using the spatial, temporal and contextual dimensions.

The main spatial challenge of maintenance work is how to notify, or learn about tasks fulfillments in real-time. For example, whether or not particular physical locations are required to be maintained. In addition, mapping the whereabouts of specific locations that are constantly required to be maintained and make their maintenance status accessible and editable real-time.

The main temporal challenge in maintenance work is to alert about real-time maintenance activities carried out by maintainers and how they get to learn about when there is a requirement to perform certain maintenance activities. For example, learn when were maintenance activities carried out the last time in physical locations such as ice skating rinks, parks, trash bins and more.

The main contextual challenge in maintenance work is how or in what way it would be possible to learn and to notify about new environmental circumstances that require attention and how to learn about these circumstances in the field.

The main spatial challenge in construction work is the physical structure of the environment, the measures and dimensions and how development work may affect the physical attributes of such environment. The challenge in construction work is also in regards to the spatial mobility of materials and supplies. There is a constant need to measure what "goes in" and what "goes out" from the construction site. The reporting challenge is to inform how materials and supplies move and are delivered within and outside construction sites.

The main temporal challenge in construction work is related to the timely progress of work and how to track down the progress of projects on a day-to-day basis.

The main contextual challenge in construction work is how to access the data and how to perform precise and physical work by using technology more fluidly in the field. Mobile technology has accommodated many new ways for construction workers to access location-based data from the field to carry out their responsibilities. However, due to contextual reasons utilization of such means were put in question.

Recommendations for the mobile service provider

The field study has resulted in gathering design process recommendations that aim to address the main challenges in construction and maintenance work and the most dominant usability issues that were located in the usability assessment.

Emphasizing structural and collaborative aspects of use situations by allowing coordination of activities: the service provider should consider integration between tasks and roles of workers to have a better streamlined flow of information. This is to correlate between the many skills and activities of each individual in the organization.

First, in individual work, for example, a maintainer whose role is to carry out maintenance missions and utilizes machines at the same time can kill two birds with one stone by submitting one report containing information about working hours and utilization of machines.

Second, in collaborative work, to allow coordination of tasks I recommend to develop a co-dependent reporting of tasks performed by teams. This is to correlate between work assignment by different individuals carrying out a joint task. For example, reported content from the task of laying X meters of pipes will automatically report that X cubic meters of loose materials was poured and so forth. This idea was discussed with construction foreman [Construction 2]. It was estimated that construction team assignments can be represented by a total of dozen categories. The implication for such approach is that workers could "check-in" together to the same

assignment through swift interactions and that joint content will automatically flow to the server.

Furthermore, in order to start implementing this approach, the service provider may examine how previous content from construction sites might contribute to calculate the quantities of materials and supplies.

Task based reporting process aims to create more fluid reporting interactions and to eliminate the creation of excessive amount of data. Such approach can be implemented by letting report content first flow top-down by letting foremen assign individual tasks to each worker. At the moment, foremen inform workers about their scheduled assignments at the beginning of workdays via WhatsApp, text messages, e-mails or face-to-face meetings. Workers carry out their work-related assignments and reporting tasks and let data flow upstream. Later, foremen play an integral part in processing this information by spending much time to approve working hour reports and to troubleshoot errors.

The idea is to have a better work balance between foremen and workers by letting information to flow first downstream. Foremen should feed daily tasks and workers should check-in and check-out. Content of report can be altered if the nature of work tasks changed, at the end of workdays either by workers or foremen. As subsequent, foremen will dedicate less time to monitor reports and more time to create assignments. Workers will only have to accept their assignments when work commences and sign out when they were concluded. If work deviated due to unexpected activities the content can be edited by both parties.

Trigger-based workflow: the system can offer trigger-based workflows to increase speed and ease of use in several ways. Some actions can be automated and others customizable by the workers themselves.

First, the system can automatically trigger data entry to correlate between the selectable categories. This can be executed by triggering one category after selection of another category, for example, between vehicles and their supplies (type of material and quantity in metrics) or even between workers and their used tools.

Second, when automated trigger-based workflow is not feasible due to frequently changeable work tasks, workers should be allowed to establish their own workflow rules and trigger their own reporting actions in relation to reporting content.

Accountability: the service provider should consider to allow workers having more access and control over their reporting content. Workers can become more proactive rather than reactive when they can better exploit the content history of reports. This can shorten time and lower the number of taps required in the reporting process. Such accountability can be achieved by allowing workers to construct ‘chunks’ of information that represent their work routines.

In addition, the service provider should consider to allow workers and foremen the ability to edit content of reports after they were sent. The majority of workers found this as a prominent issue and wished to be able to fix their errors. In order to resolve this issue, a time window that will allow to correct reports can be implemented. This can be done by suspending delivery of submitted reports to the server by a sensible amount of time.

Increase collaborative awareness: the service provider should consider implementing a better feedback mechanism after reports were sent. This may generally apply to a variety of reports, including working hour reports, but mostly applies to those that require further attention by other functionaries. The safety detection feature was overlooked by most maintainers partly due to inability to follow the status of sent hazards reports. As a result, maintainers did not know if hazards were attended to and embraced other available alternatives such as WhatsApp. As a solution it is suggested that the collaboration in the reporting process through features such as the safety detection should be kept within the application and not be extended to other means of communication such as e-mails, which are used in the back office but not in the field.

Recommendations for the workplace of the blue-collar mobile workers

The mobile service workplaces should consider to introduce more clear-cut conventions to induce and to vacate time to report from spaces such as the office and depots at the end of workdays. This to prevent situations where workers report from home, and could potentially contribute to better working experiences.

Based on the findings some changes can be made to mitigate the challenges of utilizing mobile devices in blue-collar mobile work contexts.

Blue-collar mobile workplaces should consider to acquire and diffuse tablets in several contexts of mobile work as a supplement to mobile phones. Firstly, in trucks, for the purpose of navigation in the roads and filling reports. Allocation of tablets can decrease the difficulties to navigate by using in-car navigation screens. Road maintenance work of drivers can benefit by receiving real-time location based information on tablet screens, for example, by showing snow removal routes of team members, locations of stranded busses and other obstacles and so forth. In addition, there was a lesser degree of contextual interference in the trucks and more free time to interact when truck is safely parked. This can potentially introduce more opportunity to fill reports and eliminate the phenomenon of delaying data entry by scribbling information on paper.

Secondly, in excavators work within construction sites. By adding tablet stands, for example, at the top right hand side of excavators workers could place tablets to interact

and access PDF versions of site maps. This will allow them to scale maps as much as they need.

Thirdly, in site offices and depots, where workers start and complete their workdays. Workers who were uncomfortable using their mobile phones can utilize tablets to access e-mails and for reporting purposes. This in turn can contribute to a more universal way of utilizing technology and potentially bridge generation gaps between workers.

Finally, the mobile workplaces should consider to allocate workers with better equipped site offices to run intensive administrative operations. Foremen could very well benefit from better computer monitors, ergonomic pointing devices and so forth, to support their work.

5.4 Reflections on the methodology

There were a few obstacles to overcome prior to and at very early stages of the field study that challenged the ability to conduct a genuine contextual inquiry.

First, language plays a major role in qualitative research as it is used to express and construct meaning to people's experiences. In this study, the ability to fluently converse in the field was restricted due to my limited Finnish language skills. The field interviews were fluent only for the most part and challenged my ability to ask probing questions due to problems in comprehension. To be successful in my role as a researcher I had to ask participants to provide further clarifications to their words from time-to-time. I also required further assistance in interpreting the true meaning of some statements provided by participants to not lose the richness in workers' words. A major disadvantage to the analysis process of the findings was due to my incapacity to transcribe the audio recordings, which challenged my ability to bring many comments from the field to stand in the center of the findings.

Second, early during the visits to the field it became apparent that much of the interactions for reporting purposes could not be observed in their natural settings. The observations of the reporting process were not conducted in the ideal settings and therefore could not reflect all the challenges imposed by the environment. This adds up to the already existing time and space limitations of this research to witness real-time interactions in the field. Exploring the reporting in its spontaneous and natural circumstances (when and where it really takes place) could have disclosed more information about workers' experiences, emotions and attitudes towards the reporting process. Learning about the limitations and the usability issues required to expand the limits of the investigation by exploring the utilization of other mobile solutions. Further, some participants have voluntarily demonstrated how they report and shared much of

their experiences using the M-Reporting system, which helped in gathering a good understanding of the factors that affect the reporting process.

For further research in the field, I would like to suggest to complement the conduct of the contextual inquiry with experience sampling methods that will help to collect genuine real-time experiences of workers on the go and to shed more light on what workers feel and think when they interact with mobile and information technology.

Other challenges to the research were due to the inability to have control over the selection of the participants. First, the age of participants most likely did not represent the general age of the total workforce in the organization. The relatively old age of the participants is subject to possible bias in the results of this study. Interviewing younger participants could possibly have provided more types of reporting habits and shed more light about the perceptions of using the M-Reporting system.

Additionally, in this study it was only possible to interview four construction workers, one builder, one measurer and one foreman. An additional interviewee in each role could bring new knowledge to the table. Furthermore, it was only possible to interview middle-managers in two out of the three contexts, which limited the understanding of data-generation demands in the context of road maintenance. Interviewing a higher number of workers may help to validate the findings of this study and to subsequently assess the scope needed to yield reliable results in field studying similar contexts.

Finally, I would also recommend to consider to widen research in the field in other contexts of blue-collar mobile work and in other types of organizations to improve the knowledge of use of mobile technology in more study contexts. The use of mobile technology studied in the scope of this study was of low complexity and repetitive and it could be worthwhile to further explore blue-collar duties with a higher task complexity, such as measurers in construction sites. In addition, studying the reporting process in other organizations could lead to more results regarding organizational norms and business orientations.

6. Conclusions

Nowadays, data generating demands in data-driven blue-collar workplaces such as the demand to report the outcomes of work have intensified and hold implications towards how work is experienced. Not long ago, workers were still reporting information in rather manual ways, such as in the case of the present study context, where reporting working hours was done through paper forms. In many regards, the effects of utilizing digitized means to report information contributes to the efficiency of the organization but impacts the workers who carry out larger accountability to fulfill such missions.

The aim of this thesis has been to better understand the use practices of mobile phones for the purpose of reporting by mobile workers in different work contexts. In addition, the aim was to learn how limitations and usability issues can affect the possibilities to report in physical work environments, where information solutions have been previously poorly introduced. Exploring the unique circumstances under which interactions are carried out to keep up with the reporting demands was beneficial to gather more information about what is actually taking place when complying with demands to digitally report data from the field.

A field study was conducted in a study context of one organization where blue-collar mobile workers carrying out various types of labor are required to report information about their work tasks and outcomes from the field. The contextual inquiry method was chosen to guide the field study. The field study has resulted in gathering qualitative data through interviews and observations of real mobile workers in three different contexts of blue-collar mobile work. The focus of the study was put on the use of M-Reporting, a mobile based system used by workers to send digital reports that are used for administrative and operational purposes of maintenance and construction of infrastructure.

In order to find out what kind of practices are carried out by workers in the field, theory dealing with work in multiple spaces was used as a method to analyze the practices of mobile phones use. Furthermore, the theory was used to learn about the use practices of mobile phone for the purpose reporting. The analysis has demonstrated for what purposes physical and virtual (as in tools and devices used) spaces are used and how the requirement to work from multiple spaces affects the social and mental experiences of workers.

To learn about how limitations affect the possibilities to interact with ICTs, theory engaging the concept of mobility has been used. It was demonstrated that the utilization of mobile phones in the field is faced with various spatial, temporal and contextual factors. By analyzing three contexts of mobile work with different mobility dimensions it was possible to see how different characteristics of mobile work, such as actual work

tasks, environments, physicality and organizational factors affect the possibilities to interact with mobile technology.

The usability assessment through Hertzum's images was concluded in finding that organizational and situational factors were the most problematic to the utilization of the M-Reporting system and as well as for the utilization of other tools in the field. The impact of organizational and situational factors was diverse but most importantly was found to affect the ability to flexibly diffuse within mobile field work contexts. The assessment stressed the importance of offering flexible and intuitive interfaces to be used in the field.

The field study concluded in gathering qualitative data from the field that includes insights, experiences and attitudes about the use practices and the demand to utilize mobile and information technology in three contexts of work in one blue-collar mobile workplace. The main advantage of this study is the versatility of its studied contexts, the variety of tasks carried out by its participants and the possibility to explore how diverse job characteristics affect the ability to interact with mobile and information technology.

Conducting a field study provided an opportunity to be exposed to unique circumstances of utilization of ICTs in blue-collar mobile work that otherwise would have remained hidden. It was possible to discover the limitations and learn how they affect workers who carry out physical labour and interact in different degrees of spatial, temporal and contextual mobility and compare them. Conducting observations gave an opportunity to watch workers engage in collaborative work activities that opened up a window towards an overall better understanding of the larger context of use of mobile technologies within an enterprise running complex and collaborative field operations. Retrospective accounts and insights shared by workers and by their foremen have provided meaningful input into the implications of the demands to produce and monitor data.

The study has shown that each profession contains different sets of dynamic characteristics that are needed to be addressed. Additionally, each profession holds different individual and collaborative requirements that generate different outcomes to their work. Subsequently, the reported data varies between the cases and so should the manner of how it should be reported. Overall, the study has offered significant insights into how mobile and information technology could better serve different professions and can be concluded as a successful attempt to provide new ideas to streamline data more efficiently in the field and to ease the procession of such data.

References

Babaian, Tamara, Jennifer Xu, and Wendy Lucas. 2014. Applying design principles for enhancing enterprise system usability. *Proceedings of the 9th International Conference on Software Engineering and Applications*. pp. 162-169. doi:10.5220/0005099001620169

Bakewell, Lyndsey L., Konstantina Vasileiou, Kiel S. Long, Mark Atkinson, Helen Rice, Manuela Barreto, Julie Barnett, Mike Wilson, Shaun Lawson, and John Vines. 2018. Everything we do, everything we press: Data-driven remote performance management in a mobile workplace. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI 18*, pp. 1-14. doi:10.1145/3173574.3173945

Brodie, Jacqueline, and Mark Perry. 2001. Designing for mobility, collaboration and information use by blue-collar workers. *ACM SIGGROUP Bulletin* 22 no. 3, pp. 22-27. doi:10.1145/567352.567356.

Brown, Barry, and Kenton O'Hara. 2003. Place as a practical concern of mobile workers. *Environment and Planning A: Economy and Space* 35, no. 9, pp. 1565-1587. doi:10.1068/a34231

Callahan, Ewa. 2006. Interface design and culture. *Annual Review of Information Science and Technology,* 39, no.1, pp. 255-310. doi:10.1002/aris.1440390114

Ciolfi, Luigina. 2015. Space and place in digital technology research: A theoretical overview. *The SAGE Handbook of Digital Technology Research*, pp. 159-173. doi:10.4135/9781446282229.n12.

Cohen, Rachel. L. 2010. Rethinking 'mobile work': Boundaries of space, time and social relation in the working lives of mobile hairstylists. *Work, Employment and Society,* 24 no. 1, pp. 65-84. doi:10.1177/0950017009353658

Crawford, Joanne O., Laura MacCalman, and Craig A. Jackson. 2011. Health and well-being of remote and mobile workers. *OUP Academic.* September 01, https://academic.oup.com/occmed/article/61/6/385/1387389.

Gareis, Karsten, Stefan Lilischkis, and Alexander Mentrup. 2006. Mapping the mobile eWorkforce in Europe. In: Andriessen, Jochem Henderik Theodoor Halewijn, and Matti Vartiainen (eds.). *Mobile Virtual Work: A New Paradigm?* Heidelberg: Springer, pp. 45-69.

Gibson, Melissa K., and Michael J. Papa. 2000. The mud, the blood, and the beer guys: Organizational osmosis in blue-collar work groups. *Journal of Applied Communication Research* 28, no. 1, pp. 68-88. doi:10.1080/00909880009365554.

Hertzum, Morten. 2010. Images of usability. *International Journal of Human-Computer Interaction* 26 no. 6, pp. 567-600. doi:10.1080/10447311003781300

Hofstede, Geert, Gert. J. Hofstede, and Michael Minkov. 2010. Cultures and Organizations, Software of the Mind. Intercultural Cooperation and Its Importance for Survival. McGraw-Hill.

Holtzblatt, Karen, and Hugh Beyer. 1993. Making customer-centered design work for teams. *Communications of the ACM* 36, no. 10, pp. 92-103.

Holtzblatt, Karen, and Hugh Beyer. 2014. Contextual design: Evolved. *Synthesis Lectures on Human-Centered Informatics* 7, no. 4, pp. 1-91.

ISO 9241-11:2010. Ergonomics requirements for office work with visual display terminals (VDTs) – Part: 11: Guidance on usability. Accessed April 07, 2019. https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

Kakihara, Masao, and Carsten Sørensen. 2002. Mobility: An extended perspective. *Proceedings of the 35th Annual Hawaii International Conference on System Sciences*, pp. 1756 -1766. 10.1109/HICSS.2002.994088.

Kakihara, Masao, and Carsten Sørensen. 2004. Practising mobile professional work: Tales of locational, operational, and interactional mobility. *The Journal of Policy, Regulation and Strategy for Telecommunications* 6, No. 3, pp. 180-87.

Kristiansen, Kristian H., Mathias A. Valeur-Meller, Lynn Dombrowski, and Naja L. Holten Møller. 2018. Accountability in the blue-collar data-driven workplace. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems - CHI 18*. pp. 1-12. doi:10.1145/3173574.3173906

Kurland, Nancy B., and Diane E. Bailey. 1999. Telework: The advantages and challenges of working here, there, anywhere, and anytime. *Organizational Dynamics* 28, no. 2, pp. 53-68.

Luff, Paul, and Christian Heath. 1998. Mobility in collaboration. *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work - CSCW* 98, pp. 305-314. doi:10.1145/289444.289505.

Mitchell, Val, Andy May, Sarah Bowden, and Tony Thorpe. 2006. Using mobility as a conceptual framework for informing the design of mobile ICT for construction professionals. *Proceedings of the 8th Conference on Human-computer Interaction with Mobile Devices and Services – Mobile HCI* 06, pp. 45-46. doi:10.1145/1152215.1152225.

Orr, Julian E. 1986. Narratives at work. *Proceedings of the 1986 ACM Conference on Computer-supported Cooperative Work - CSCW* 86, pp. 62-72. doi:10.1145/637074.637077.

Patton, Michael Quinn. 1990. Qualitative Evaluation and Research Methods. 2nd edition. Newbury Park, CA: Sage

Perry, Mark, Kenton O'Hara, Abigail Sellen, Barry Brown, and Richard Harper. 2001. Dealing with mobility: Understanding access anytime, anywhere. *ACM Transactions on Computer-Human Interaction* 8, no. 4, pp. 323-347.

Reyes-García, Victoria, and William D. Sunderlin. 2011. Why do field research? In: Angelsen, Arild, Helle Overgaard Larsen, Jens Friis Lund, Carsten Smith-Hall, and Sven Wunder (eds.). *Measuring Livelihoods and Environmental Dependence: Methods for Research and Fieldwork*. Taylor and Francis, pp. 17-32.

Rossitto, Chiara. 2009. Managing work at several places: Understanding nomadic practices in student groups. *Master's thesis, Royal Institute of Technology*.

Singh, Akash, and Janet Wesson. 2009. Evaluation criteria for assessing the usability of ERP systems. *Proceedings of the 2009 Annual Research Conference of the South African Institute of Computer Scientists and Information Technologists on - SAICSIT 09*, pp. 87-95. doi:10.1145/1632149.1632162

Smolander, Kari, Matti Rossi, and Samuli Pekkola. 2016. Collaboration change in enterprise software development. *Proceedings of the 9th International Workshop on Cooperative and Human Aspects of Software Engineering - CHASE 16*, pp. 68-74. doi:10.1145/2897586.2897590

Tarafdar, Monideepa. 2018. Mobile, remote and blue-collar: Using information and communication to elevate workplace well-being. *Proceedings of the 26th European Conference on Information Systems: Beyond Digitization - Facets of Socio-Technical Change (ECIS).* pp. 23-28

Vartiainen, Matti. 2006. Mobile virtual work - Concepts, outcomes and challenges. In: Andriessen, Jochem Henderik Theodoor Halewijn, and Matti Vartiainen (eds.). *Mobile Virtual Work: A New Paradigm?* Heidelberg: Springer, pp. 13-44.

Vartiainen, Matti, and Ursula Hyrkkänen. 2010. Changing requirements and mental workload factors in mobile multi-locational work. *New Technology, Work and Employment* 25, no. 2, pp. 117-135.

Yuan, Yufei, and Wuping Zheng. 2009. Mobile task characteristics and the needs for mobile work support: A comparison between mobile knowledge workers and field workers. *Eighth International Conference on Mobile Business*, pp. 7-11. doi:10.1109/icmb.2009.9

Appendix A

CONSENT TO PARTICIPATE IN A THESIS RESEARCH

I ask you to participate to a field study, which is part of my Master Thesis in Human-Technology Interaction Degree Programme in Tampere University. By participating in this research you will help me to study mobile use of mobile workers and to improve the process of mobile reporting.

The study itself will be done during your work day. During the study I will ask you to perform your ordinary tasks and to describe what are you doing when using a mobile phone for work related purposes. Simultaneously, I will ask questions related to the use of the M-Reporting mobile application. In addition, I will ask you to fill a background information form.

Conversations during the study will be fully voice recorded and video recorded upon the use of the mobile application in order to further analyzed to improve the process of mobile reporting. All the recordings will be treated confidentially and they will be shared only with my thesis supervisor. All the recordings will be deleted after the thesis is ready.

The results of this research will be reported in a way that individual participants cannot be identified. I will use participant codes (Driver 1, Maintainer 2. etc.) and when needed I will also delete detailed information of your department.

The results of this research will be delivered to the service provider of the mobile reporting application so that they can further improve the service. Any recordings or personal information collected during the study will not be handed over.

You can choose to stop the experiment at any point.

By signing this form, you will accept the above terms.

I have read and understood the terms and decided to participate to this research.

Date and place: _____

Signature: _____

Name: _____

Appendix B

BACKGROUND INFORMATION FORM

Personal information

Age: _____

Sex: [ ] Male [ ] Female

Department: Job title:_____

[ ] Vehicle services

[ ] Repair services

[ ] Maintenance services

[ ] Geographic data and information services

[ ] Construction services

[ ] Other, what? _____

Mobile phone use for the purpose of reporting

How often do you use the mobile reporting application in order to report?

[ ] Less than once a day

[ ] Once a day

[ ] 2-4 times per day

[ ] More than 5 times per day

[ ] Other, how often? _____

How often do you need to check something from the mobile reporting application?

[ ] Less than once per day

[ ] Once a day

[ ] 2-4 times per day

[ ] 5-9 times per day

[ ] More than 10 times per day

[ ] Other, how often? _____

How long have you been using the mobile application in question?

[ ] Couple of weeks or months

[ ] Approximately a year

[ ] 2-3 years

[ ] 4-5 years

For what reporting purposes do you using the mobile application? You can choose multiple options.

[ ] Working hour log
[ ] Driver log
[ ] Location info
[ ] Off tracking
[ ] Machine report
[ ] Safety detection
[ ] MVR
[ ] Repair
[ ] Machine inspection
[ ] Safety check
[ ] Maintenance safety walk
[ ] Site check
[ ] Site introduction
[ ] Environmental observation
[ ] Firework permit
[ ] Other, what? _____

Have you recently been in contact with your foreman concerning problems in the application?

[ ] No

[ ] Yes – Tell what was the problem

_____

_____

_____

Participant code: _____