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Enhancing Cooperation for Nomadic Workers

New Possibilities in Traditional Mobile Work Environments

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Cand Scient Thesis

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Abstract

This thesis focus on design requirements for ICT-applications supporting mobile cooperative work. Mobile computing is often concerned in making traditionally stationary workers more flexible by increasing their mobility, while the problem domain in this thesis is the work environment of blue-collar workers and customer consultants, professions that traditionally have been mobile. Making these workers more mobile and flexible would require other means than increasing their geographical mobility. Cooperation supported by mobile ICT is proposed as a solution for performing assignments and deal with mobility more efficiently.

The theoretical framework is primarily based on research from the CSCW-field, and gives concepts for discussing cooperative work, mobility, and both contextual and technical perspectives on ICT. Activity Theory is used as a tool for analyzing the empirical material gathered in six case studies. By discovering potential breakdowns in an activity system, this analysis results in four categories of requirements that should co-exist in the design of CSCW-applications. Some of the results are examined in a prototype.

The categories of *usability* and *technology* address individual requirements, which is important in order to support each user's appliance of the system. The categories of *mobility* and *cooperation* address contextual requirements, which is important in order to understand how a CSCW-application will influence the existing work practices, organization of workers and division of labor.

Preface

This paper is my Candidatus Scientiarum thesis in Information Systems at the Department of Informatics, University of Oslo. The work has been conducted from the autumn of 2002 to the spring 2004.

I would like to thank my tutors, Kristin Braa and Petter Nielsen, for valuable guidance and criticism throughout the work of this thesis.

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Chapter 1

Introduction

The focus of this thesis is to examine and elicit design requirements for applications that support mobile cooperative work. These design requirements have a broader definition in this thesis than is found in a software requirements specification. Design requirement are here criteria and conditions, both technical and contextual, that should be adequately met in order for an application to succeed in a mobile work environment with a high degree of cooperation. These requirements exist on both an individual and a contextual level. Individual requirements address needs that individual users have, and the technical possibilities and constraints that exist in meeting the needs of the users. Contextual requirements address issues that designers should be aware of in the development of an application. These issues are, for example, how mobility influences work practices and the existing cooperation in organizations.

The work of the thesis has proceeded in three main steps. The first step is to study and gain an understanding of mobile cooperative work through both literature and empirical studies of blue-collar-workers[1] and salesmen. In conducting the case studies, three concepts were initially decided to focus upon; *cooperation*, *mobility* and *use of ICT*. The results of the case studies are presented in regard to these three concepts.

The second step is to outline design requirements based on these studies. The work practices, focusing on the three initial concepts, are analyzed using Activity Theory. Work practices are organized and analyzed in an activity system, and design requirements are elicited from existing or potential *breakdowns* in the mediation between various parts of the activity system. Thus, the design should solve and contribute to over-

[1] Craftsmen and skilled laborers, as compared to white-collar workers.

come these breakdowns. The design requirements exist on at least two levels. On an individual level, requirements address both *usability* and *technology* aspects, for example, how fast should a mobile device connect to a remote server in order to be user-friendly. On a contextual level, requirements address organizational work practices and structures, especially those that are influenced by *mobility* and *cooperation*. For example, how should an application be designed in order to respond to the management's desire for control, and simultaneously not be too monitoring toward employees.

The third step is to examine some of these elicited requirements in a scenario and a prototype. The scenario has two main purposes. First, based on the studied nomadic work environments, it proposes more effective work practices based on cooperation. Second, it attempts to visualize some of the functionalities that an application should have. The purpose of the prototype is to examine some of the elicited requirements, implement some functionalities from the scenario, and evaluate whether this prototype approach can meet common criteria of good software design in a software engineering sense of what good design is.

1.1 Motivation

Due to the former explosive growth of mobile markets (Riggs, Taivalsaari, and Vandenbrink 2001, p. 1), mobility and mobile computing have become hot topics among both researchers and commercial actors. The Nomade 2007-project (Julsrud, Mjøvik, Yttri, and Nielsen 2002) was one effort by the R&D department in Telenor to elicit requirements and requests for new mobile services in nomadic work environments. This was done by conducting in-depth studies on three groups of mobile workers; advisers, blue-collar workers and salesmen. Concerning blue-collars;

> "The needs of the industry open up for a range of exciting mobile applications specific for the industry as a whole and for the various branches individually, and generic applications that may be employed by professions other than blue-collars" (*ibid.*, p. 55, my translation).

Examples are applications for time planning and management, documenting purposes, job overview and status, and "joint calendars" for supporting networks.

The motivation of this thesis is to examine how mobile ICT, beyond generic services such as voice and SMS, can contribute to and support the cooperation in nomadic work environments of blue-collars and salesmen. The scope of the thesis is applications that specifically address cooperation and are developed for this purpose. Grudin (1994b) proposes eight challenges for developers of computer systems, also referred to as groupware and CSCW[2]-applications, that support cooperation. He claims that in the instances where groupware fails, it is often because developers do not understand the complexity and the demands that groupware "imposes on developers and users" (p. 93). This thesis suggests that the complexity of a CSCW-application will increase when mobility is added to the picture, and the thesis will propose requirements that follow from this complex problem domain.

The case studies in this thesis suggest that the traditionally geographical mobility of blue-collars has limited their possibility of cooperating in a flexible manner. Each worker is attached to his own assignments, and must in general only relate to his superior. Thus, work is vertically and hierarchically organized. This thesis proposes that work can be organized in more flexible and efficient manners by the aid of ICT. However, the focus is not on organizational design, but design of ICT as a tool for enabling more flexible cooperation.

The motivation for companies to organize work differently is efficiency, and consequently economic motives. By saving time and efforts in organizing and coordinating work, this should also be reflected on their account balance in a positive direction. However, potentially economic prosperity is not always motivating enough. Managements in the studied companies expressed reluctance in making changes in the established organization of work, even though they admitted that other routines might be more efficient. The case studies also suggest that companies did not achieve the full benefit of ICT, because they were not willing to adjust the organization of work and the existing routines.

However, this should not demotivate an examination of how a CSCW-application *could* function in such a nomadic environment. This thesis also suggests that the positive economic effect of ICT supporting cooperation will be more visible in larger companies than the ones studied. It will also be more purposeful to implement such a system in larger companies, because the complexity of the organization increases with the number of employees and assignments, and it is this complexity that ICT is intended to deal with.

This thesis reflects upon ICT from both a technical and a social point of

[2]Computer Supported Cooperative Work

view. While Information Systems (IS) research often focus on the context of ICT, this thesis attempts to merge both contextual and technological aspects. The arguments for a technological approach in this thesis are motivated by Orlikowski and Iacono (2001), who call for a greater focus on artifacts in the IT research. During the 1990s, technology has to a great extent been black-boxed as a stable and constant parameter by IS researchers. By studying and classifying all the published articles in Information Systems Research[3] during the decade, they found that IT artifacts were under-theorized. "Currently, in the one journal most focused on publishing IS research, we see that information technology is not a major player on its own playing field" (*ibid.*, p. 130). The conceptualization of Information Technology is classified into five main perspectives; *nominal*, *computational*, *tool*, *proxy*, and *ensemble* views. According to the authors, the *ensemble* view is clearly under-represented. This view tries to capture both technical and social aspects of IT, and this thesis is inspired by the ensemble perspective.

1.2 Problem domain

The main problem domain of this study is the work environment of blue-collar workers, in this thesis primarily electricians and plumbers, and the use of ICT related to their work. As a mean for comparison, also salesmen are part of this study, but to a much smaller extent. After studying three blue-collar companies, some general features can be described; Blue-collars work in a nomadic environment, in the sense that they work on different locations for shorter or longer time-spans. They may also be mobile within a working site, which also is described in literature (Luff and Heath 1998). Their primary work is the tasks that generate their income, that is the actual jobs they do for their customers, for example fixing a faucet, installing pipes or wires. In addition to this primary work, a lot of effort is also put into administrating, preparing and organizing these tasks. This administration is here called secondary work, and consists of traveling to working sites, collecting materials at wholesalers, registering hours and materials, making invoices and other administrative tasks. The list of secondary work is long and various, but the correspondence between the tasks is that they are often negatively considered as loss of time and income. For example, a large amount of time is spent on registering information related to assignments, due to the fact that workers "in the field" register all their information on papers. This information, spread on different papers and sometimes written in an unreadable manner, has to be manually entered into the company's ERP-system by secretaries or administrators. Thus, the same

[3] http://isr.katz.pitt.edu. Accessed May 10th 2004.

information is registered twice, or even more times. The blue-collar companies studied in this thesis have tried to solve this problem by implementing an ICT-solution that enables workers “in the field” to electronically register assignment information. This has cut administration costs considerably, and is one example of how ICT can increase efficiency in mobile organizations.

The work of salesmen, also referred to as customer consultants, is quite equal to the blue-collars in terms of not having a fixed work location. However, the primary work of the two professions can not purposefully be compared. The secondary work of salesmen is more interesting to compare to the secondary work of blue-collars, even though salesmen have considerably less information to receive and register. Both professions are mobile, they have to cooperate and be coordinated. The case studies suggest that salesmen cooperate in a more flexible manner than blue-collars, and one reason for this is that their work is more team-based. This will be further discussed, but the conclusion of this section is that common features of the work of blue-collars *and* salesmen are *cooperation*, *mobility* and *use of ICT*.

1.3 Goals

The primary goal of this thesis is to give advices and highlight important issues in the design and development of applications that intend to support cooperation in nomadic work environments. In doing so, one should first establish an understanding of which roles cooperation, mobility and ICT play in these work environments. Next, the requirements and challenges of designing such applications will be analyzed and discussed based on the understanding achieved by literature and empirical studies.

An application that intends to support mobile cooperative work must relate to a complex world, because it supports workers in various settings and situations (Sommerville 2001). The system consists of a various number of mobile terminals carried by mobile workers in the field, and stationary terminals at offices. This thesis tries to capture the complexity of the problem and application domain, by assembling the features that must successfully *co-exist* in a mobile CSCW-applications. These features, that are derived from the Activity Theory analysis, are divided into four main categories; *usability*, *technology*, *mobility*, and *cooperation*. In order for a mobile CSCW-application to succeed, the thesis suggests that requirements within all of these categories must be met adequately. These categories are general concepts within mobile computing and CSCW-research, but serves as containers for more specific requirements related to these categories. The main contribution of this thesis is to:

1. Present and discuss the results of the conducted studies from nomadic work environments, that is, work practices of blue-collars and salesmen. The analysis results in specific design requirements, not as a complete requirements specification, but interesting phenomena from the gathered empirical material are highlighted.

2. Give advices for design of mobile CSCW-application. Design must equally address individual and contextual requirements.

3. Give ideas for organizing work more efficiently by the aid of ICT. These suggestions are presented in a scenario, and are based on ideas of how the studied companies could alternatively organize work.

After some preliminary studies, work hypotheses were elaborated. These hypotheses were based on literature studies and preconceived opinions based on "common sense" and experiences with blue-collar workers. First, blue-collars work in an environment with a high degree of mobility and cooperation. Thus, the study must focus on how this influence the work of blue-collars. Second, blue-collars have a high threshold for adopting work-related ICT technology except for mobile phones. This view is based on the notion of blue-collars' reluctance of office work. Developing work-related applications for mobile phones may lower the threshold, because mobile phones are already adopted by most blue-collars.

The goal of this thesis is to study mobile workers' routines and how they employ existing ICT, and transform the results of the studies into design requirements of mobile CSCW-systems. This goal is formulated in the following problem definitions:

1. *What are the important features of mobile cooperative work?*
2. *Which ICT design requirements are brought forward by these features, and could enhance the cooperation in mobile work situations?*

1.4 Methods

The goal of this thesis is to gain understanding of mobile cooperative work and elicit requirements for mobile cooperation systems development, thus, the applied methodologies must be chosen according to these problems. The bipartite approach to my problem may require use of different methods. On the theoretical level, exploring mobility and mobile work, a qualitative research method is most applicable. On the practical level, the development of a limited part of a mobile ICT system will be based on the ideas generated through the preceding theoretical studies and the gathered empirical material. Prototyping may be an effective method in meeting the high degree of uncertainty in the design of a CSCW-application, and this will be evaluated as well.

1.4.1 Case studies

In collecting empirical data by conducting case studies, I and three other cand. scient. students collaborated closely. Even though we did not share the same problem definitions, this had some clear advantages. The validity of the empirical findings increased through investigator triangulation (Guion 2002). "Investigator triangulation involves using several different investigators/evaluators in an evaluation project" (p. 2). Results were discussed and related to our own problem definitions. This kind of evaluation turned out to be valuable. In a number of cases, there arose dissent on what we really had observed. Then we had to contact the participant again for clarifications. More data were collected since we shared interview objects and company visits between us. Each student could build their thesis on a larger sample of data, than would be possible if case studies were conducted individually. This also increases the validity of the findings, since it is an example of data triangulation. Different groups of stakeholders were identified, and the opinions of these were compared. "The weight of the evidence suggests that if every stakeholder, who is looking at the issue from different points of view, sees an outcome then it is more than likely to be a true outcome" (*ibid.*, p. 1). In the analysis of the empirical material, an interesting point was also to see where stakeholders disagreed in order to find potential conflicts.

The case studies in this thesis consist of:

- Interviews. Data were primarily collected through 16 interviews with developers of mobile computer systems, company management, blue-collars and customer consultants. Interviewing different participants in the problem domain was important in order to collect different viewpoints.

- Observations. 3 observations were conducted on mobile workers, both blue-collar workers and salesmen. Mostly, this was done to get some "real-life" impressions of how they carry out their work. It was not possible to follow them closely for an extended period of time. Thus, our knowledge of their work is basically founded on what they told us in interviews.

In order to create a good research design, some criteria were outlined, based on Yins guidelines (1989). First, objectives and questions were articulated in interview guides. These interview guides contained questions from all four student, thus not all questions were relevant for each student. Second, each student had to link their questions and objectives to their own study. Third, the empirical evidence was gathered through interviews and observations, and analyzed both individually and by the students as a group.

1.4.2 Scenario-based design and prototyping

Scenario-based design is used for two purposes. First, it summarizes and visualizes the proposed functionalities in a future CSCW-application for designers and potential users. Second, it suggests new ways of organizing work in blue-collar environments, and visualizes the potential of a mobile ICT-solution.

Some of these functionalities are explored in a prototype. The purpose of the prototype is learning and evaluation. The goal of the prototype is to explore how requirements can be implemented, and if criteria of good design (Mathiassen, Munk-Madsen, Nielsen, and Stage 2000) can be met by using a prototype approach.

1.5 Structure of the thesis

Last part of this chapter is a summary of each chapter, how they contribute to the thesis and how they relate to each other.

Chapter 1. Introduction

The first chapter presents motivations and goals for this thesis and an introduction to the problem domain of blue-collar workers and salesmen. A brief outline of methodological approaches are also presented along with this summary of chapters.

Chapter 2. Mobile cooperative work

The theoretical framework is established as a foundation for further discussions on mobility and computer-supported cooperative work. The choice of Activity Theory as a tool for analyzing the empirical material is discussed, and the applied concepts from this theory is presented. The framework of terms and theories are applied in chapters five to seven.

Chapter 3. Mobile computing

This chapter also presents theoretical terms, but it has a more technological focus. Mobile computing requires both hardware, such as client terminals and networks, and software, such as applications and middleware. A smart-client architecture is presented as the purposeful design architecture to use. The features of Java^{TM}2 Micro Edition are presented, because the prototype is developed using this technology.

Chapter 4. Methods

How the empirical data were collected is presented in chapter four. Various perspectives and methodologies within qualitative research is presented and discussed. The choice of case studies as the applied method is discussed, along with a description of how the work of these case studies proceeded. In the second part of the chapter, the use and different kinds of prototyping are presented and discussed.

Chapter 5. Case study results and analysis

The results of the conducted case studies are presented in chapter five, and findings are discussed in light of the theoretical framework in chapter two, focusing on *cooperation, mobility* and *use of ICT*. The discussion is related to the first problem definition. Activity Theory is applied as a analytical tool in analyzing and discussing the mobile cooperative work, organized in an activity system.

Chapter 6. Designing applications

Chapter six presents the design requirements, derived from the Activity Theory analysis' breakdown concept. These requirements address *usability* and *technology* requirements on an individual level, and *mobility* and *cooperation* on a contextual level. Requirements within these four categories are presented in respective sections in this chapter.

Chapter 7. Evaluating the prototype

First part of chapter seven is a description of a future scenario, based on the use of a CSCW-application to support cooperation. The second part of the chapter is an evaluation of the prototype, examining the elicited requirements in chapter six.

Chapter 8. Conclusions

Conclusions of the thesis and answers to the problem definitions are outlined, and proposals for further research are presented.

Chapter 2

Mobile cooperative work

This chapter presents various aspects and key terms of mobile cooperative work, and a theoretical framework is established for my further discussions. The purpose is to give a set of concepts for analyzing and discussing *cooperative work*, *mobility*, and *design* of ICT supporting mobile cooperative work. These terms are the backbone of this thesis and will appear throughout the paper.

One of the main concerns in this thesis is to study how blue-collars work in terms of cooperation. Thus, it is natural to see what theories the CSCW-field may offer in the study and analysis of such work. As a multidisciplinary research field, with contributions from computer scientists, anthropologists, sociologists, organizational theorists and social psychologists (Grudin 1994a), CSCW offers theories on both work practices and ideas for mobile computing and technology. CSCW-applications, often referred to as groupware, pose other challenges to designers than single-user systems. These challenges will be presented in the section of groupware. Activity Theory is chosen as the theoretical framework to analyze and discuss mobile cooperative work. The theory is first and foremost an analytical tool, which was chosen after the case studies were conducted. Scenario-based design is proposed as a perspective to use in the process of designing CSCW-applications. For the sake of clarity, cooperative and mobile work are separated and treated in different sections. How they relate to each other will be discussed in chapter five and six.

2.1 CSCW

The study of cooperative work and use of ICT is the main agenda for CSCW researchers. The term "Computer Supported Cooperative Work" originates from a workshop organized by Paul Cashman and Irene Grief in 1984, which gathered people from various disciplines with a shared interest in how people work and how ICT could support them (Grudin 1994a). Traditional topics of research have been the development of theories of collaborative work and methodologies for analyzing such work and designing CSCW-systems. Designing software for a group of people instead of individuals poses a series of new challenges to the designers, because the number of parameters increases.

2.1.1 Theories for studying work and organizations

Before designing systems, analyzing and describing work and the context of work is an important part of eliciting system requirements. Theories are established and developed by researchers in order to analyze and describe work in a structured and communicative way. Generally, a theory "is a set of key distinctions for observing, participating, and designing. It is [...] the eyes with which we see what is going on" (Flores, Graves, Hartfield, and Winograd 1988, p. 154). Three different theories have been considered as tools for analyzing and discussing the empirical material, and Activity Theory was chosen as the most suitable, much because of its concept of breakdowns which will be actively applied in the analysis.

Structuration Theory has been used and found purposeful in analyzing organizational structures and how technology affects these (Scheepers and Damsgaard 1997). A key principle is the duality of structure; human activities are enabled and constrained by social structures, and at the same time these structures are produced and reproduced by the activities. The theory was developed by Anthony Giddens as a sociological meta-theory, and essential in human action in organizations are three elements which are created and recreated; meaning, power and norms (Orlikowski 1992).

A Structuration Theory analysis of blue-collar companies could for example include studies of how ICT influences the structures of power in a company. As the analysis of one case in this thesis suggests, mobility and "invisible workers" incited the managements' desire of controlling the employees. They were eager to use their ICT system to exercise control over employees. For examples, some fields in control lists were substituted with nonsense messages in order to check whether workers actually did read the control list before they checked the boxes. ICT is a facility for reproducing and strengthening structures of power in this company.

Structuration Theory demands a thorough mapping of social structures within an organization, which poses methodological problems discussed in chapter four. Using this theory would require far more access to participants than we were allowed to in companies. In addition, being so focused on organizational structures and social processes, Structuration Theory is found outside the scope of this thesis, and will consequently not be applied.

Actor-Network Theory (ANT) originates from sociology and the interdisciplinary field of STS[1] in the 1970s and has later been elaborated by e.g. Latour, Callon and Law (Law 2000). Some of the key elements in ANT applied in Information Systems research is the dissolution of the common notion of dividing acting human subjects and passive technological objects (Monteiro 2000). ANT sees the world as one network of human beings and artifacts, both with the possibility to act upon each other, and consequently named actants. Taking blue-collars as an example, they are part of a large network including colleagues, blue-collars of other professions, enterprises, wholesalers, customers, tools etc. Often, these actants have to communicate, they are dependent of each other and must cooperate. An ANT analysis of nomadic blue-collar environments could include a study of how ICT, more specific mobile phones, as an actant supports or disrupts the cooperation and mobility of workers.

There are several reasons for not applying ANT in this thesis, since the problem statements treat with human interaction and human-computer interaction. While Monteiro (2000) argues for the use of ANT on all levels of analysis, Engeström and Escalante (1996) claim that there is a “missing link” in the ANT when it comes to analyzes on a micro level. “From the perspective of human-computer interaction, a particularly problematic feature of actor-network theory is the elimination of the specificity of the activities and interests of end users” (*ibid.*, p. 345). In Information Systems research ANT is applied in analyzing larger networks of people, organizations and technology. The suitability for using ANT in analyzing work processes and eliciting systems requirements on a small scale would therefore be questionable, because the theory does not offer concepts for this thesis. “The concrete activities and actions of makers and user - engineers, shop-floor workers, consumers, and other - have received little detailed attention in the actor-network genre of studies”(*ibid.*, p. 344).

[1] Science and Technology Studies

2.1.2 Activity theory and blue-collars

Engeström and Escalante (1996) propose **Activity Theory** as suited for the task of analyzing "systematically the inner dynamics of "a small, dynamic, entrepreneurial company"", because the theory has "developed a conceptual toolkit and a reservoir of empirical case studies" (*ibid.*, p. 365). Activity Theory (AT) originates from the Soviet cultural-historical school of psychology, founded by Vygotski, Leontjev and Lurija, and inspired by philosophers like Hegel and Marx. The concept of activity has later been found adaptable to the analysis of disciplines other than psychology too, but mainly within the social sciences. "Broadly defined, Activity Theory is a philosophical framework for studying different forms of human praxis and developmental processes, with both individual and social levels interlinked" (Kuutti 1991, p. 253).

One reason for using Activity Theory in this thesis is that the concept of activity offers a range of valuable terms in the analysis of work, both on an interpersonal level and a human-computer level. "With Activity Theory we got an integrated theory capable of dealing with both human-computer and human-human interaction/communication. ATs distinction between *communicative* and *instrumental* actions is in this respect very clarifying" (Svanæs 2000, p. 60, author's emphasis) In addition, previous work has been purposeful to use in the building of the theoretical framework. The presentation of AT is based primarily on the work of Bødker (1991), Kuutti (1991), Bardram (1998), Svanes (2000), and Engeström and Hasu (2000).

"Activity Theory seems to provide appropriate conceptualizations, suited for analyzing cooperative work, its dynamic transformation, and the importance of cooperative breakdowns" (Bardram 1998, p. 91). In this section, the applied conceptualizations of activities will be presented. The concept of breakdowns is especially important, since it will be used to understand changes in work practices and in eliciting design requirements for cooperative work. The applied terms and concepts of AT are presented and exemplified in a description of a general blue-collar work context.

Activities are performed by *subjects*, that is a human being or a group of people, and activities are bound to certain *goals* and/or *objects*. Finishing an assignment is a typical goal in a blue-collar company, and it will be carried out through a *collective* activity of various people. This collective activity is the sum of *individual* activities, such as registering customer information, doing the actual tasks, and making invoices based on hour and material lists. "The individual [...] activity has a goal or we can say that it is directed toward an object" (Bødker 1991, p. 21). Activities are carried out in *actions* or chains of actions (Kuutti 1991), with specific *intentions* of what ought to be done (Bødker 1991). One action of a blue-collar may be to move from the office to the working site in a car. Actions are realized through several operations. While actions are conscious units, operations are sensomotoric units. Hammering a nail is normally considered an operation for a carpenter, because he will not contemplate doing it. However, if something goes wrong, his attention is brought to the problem and becomes a conscious action. In that way, operations are *conceptualized*, and this often takes place in *breakdown situations* (*ibid.*). These situations occur when assumed conditions for operations do not match with the actual condition. In designing systems, an important part of the work consists of predicting conflicts that may occur related to the use of the system. What became evident in some case studies was that companies put a lot of effort in preventing organizational breakdowns. In one company, horizontal cooperation for solving ad hoc-incidents was restricted due to the fear of chaotic situations that might occur. Instead, ad hoc-situations were solved vertically, that is, workers contacted their foremen which decided the measures of solving the occurring problems.

Furthermore, activities have two important sides; a *communicative* and an *instrumental* side. "To organize, coordinate, and control the collective activity, **communication** plays a role" (*ibid.*, p. 21, author's emphasis). The activities of foremen in the office will to a large extent be communicative, for example when the foreman explains employees what to do, that is, direct the activity toward other subjects. Activities directed toward objects are instrumental, for example plumbers installing pipes. Another important feature of an activity is the use of *artifacts* (*ibid.*), also referred to as *tools* (Kuutti 1991). Both communicative and instrumental sides of the activity may be *mediated* by tools. For example, the registering of an assignment has the communicative aspect of informing the employee, while the foreman might use a computer in physically typing the information.

Bardram (1998) proposes AT as a conceptual frame for understanding *dynamics* of cooperative work. "Understanding the dynamics of cooperative work is extremely important as a way to understand how to design computer systems supporting cooperative work" (*ibid.*, p. 89). By dynamic, Bardram means that cooperation develops and changes over time. Furthermore, breakdowns are important to understand, both how they occur and how workers recover from breakdowns. Collaborate activity can be divided into three hierarchical levels: co-ordinated, co-operative and co-constructive activity. Co-ordinated activities are the

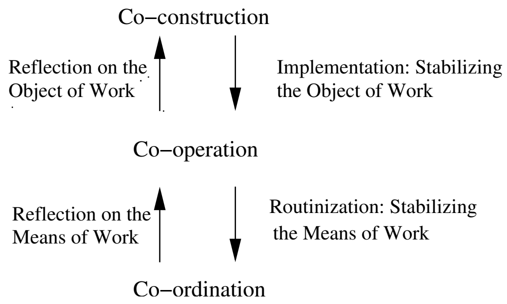

Figure 2.1: The Dynamics of Cooperative Work

harmonic aspect of work, a normal work situation. However, in this mode, workers do not relate to the common object, they are wheels in a machinery, passive participants. Co-operative collaborative work also refer to a stable situation, but in this mode workers focus on their common object, not only what they are told to do. The subjects of an activity becomes active. Figure 2.1 (Bardram 1998, p.92) displays the dynamic transformations between the different levels. Upward transformations are normally caused by breakdowns or a deliberate shift in focus. Workers then have to reflect on the means or object of work. Downward transformations occur when routines first are re-established, implemented and stabilized into the work environment. Cooperative work on a normal day in a blue-collar company will presumably exist on a co-ordination level, when everybody sticks to the normal routines of work. Workers on a common working site will probably work on a co-operative level, since they "share the objective of the collaborative activity" (*ibid.*, p. 91). A transition to the co-constructive level happens when ad-hoc situations occur. For example, this might happen when working plans are changed.

Summing up activity theory, it would be hard to avoid the classic model, figure 2.2, of Engeström (Hasu and Engeström 2000, p. 64). It explains how important aspects of an activity are related to, and mediates each other. For example, tools are the mediator between the subject and the object. If the tool, that is the CSCW-application in this thesis, does not meet usability and technological requirements this may cause breakdowns in the mediation between the subject and the object. *Rules*, explicit and implicit norms and regulations, mediates between the subject and the *community*, the group who share the same object. For example, work practices are often regulated by rules, and the introduction of ICT may influence these rules, or even produce new rules and work practices, accompanied by potential breakdown situations. The *division of labor*

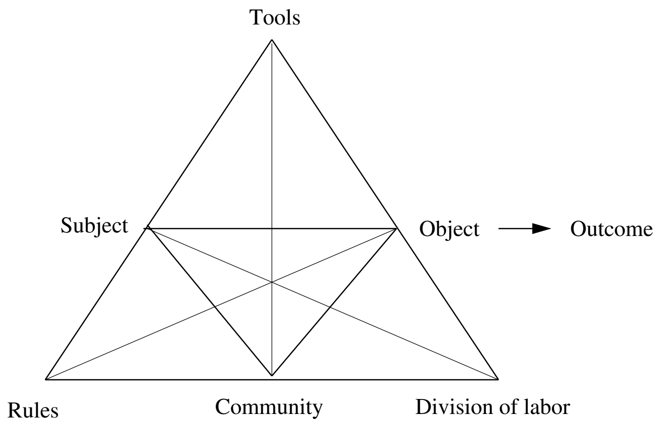

Figure 2.2: The mediational structure of an activity system

is both considering horizontal division of work and vertical division of power and status (*ibid.*, p. 63). If the division of labor is altered by the introduction of ICT this may cause breakdowns if employees think their increased share of work is unfair. In the analysis of blue-collar workers, these presented terms will be applied. A particular focus is put on the breakdown concept, both in regard to dynamic transformations in collaborate work, and in the different parts of Engeström's model.

2.2 Mobility and mobile work

Extensive work has been done on the vast subject of mobility, and an in-depth discussion of mobility would fall outside the scope of my thesis. Traditionally, mobility has been connected to geographical mobility, the "ability to move or to be moved, capacity for movement or change of place"[2]. Blue-collars and salesmen are also traditional mobile workers, because their job implies that they are on the move.

Kristoffersen and Ljungberg (2000) have a straight-forward approach when they introduce different *modalities* of mobility. These modalities are generalized patterns of motion; *traveling*, *wandering* and *visiting*. In this thesis, the term *geographical mobility* is proposed and used as a common term for these modalities of mobility. Patterns of movement is also used to describe work practices influenced by mobility in the analysis of the case studies.

Traveling is the process of moving from one site to another in a vehicle.

[2] Oxford English Dictionary Online; http://dictionary.oed.com

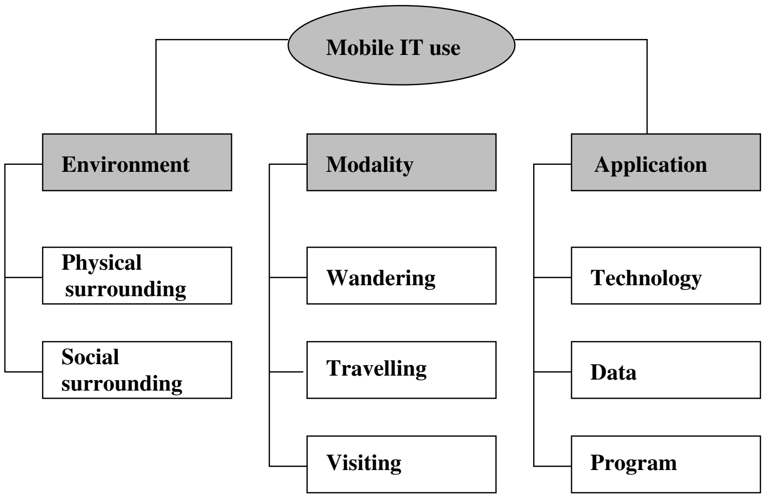

Figure 2.3: Model of mobile IT use.

Wandering is extensive local mobility, moving around in a building or a local area. Visiting is staying in one place for a prolonged period of time before moving on. In addition to how workers move, mobile IT use is also dependent of the *application* and the *environment*, shown in figure 2.3. The application consists of three components; *technology*, *program* and the *data*. A further discussion of these topics will be continued in the next chapter, since it deals with the technological part of mobile IT use, also referred to as mobile computing. The environment is the context in which the use of information technology takes place. This includes both social and physical surroundings. In this thesis, the environment of blue-collar workers and salesmen is studied through interviews and observations.

This model is appropriate in this thesis for several reasons. First, it offers concepts to both individual, contextual and technological issues in this thesis. The modalities of mobile IT use describes how each individual worker move, but it is also important to study the environment, the context, in which they work. Developing a mobile software system requires considerations of all these three concepts. Second, it captures the interdependent factors of mobile computing as a whole. While others may focus on particular parts of mobile computing, be it human-computer interface or networking, Kristoffersen and Ljungberg tries to define both body and parts.

Luff and Heath (1998) also have a spacial approach to mobility when they define three types of *physical* mobility; *micro*, *local* and *remote mobility*, but in contrast to Kristoffersen and Ljungberg, they focus more on mobility of artifacts. They do this by studying three different settings for mobile collaborative work with object-centered actions. Micro-mobility is present in the handling of a medical record in a primary health care office. The location may be small but the document is a critical resource in the communication and collaboration of medical staff, doctors and the patient. Remote mobility can be traced at a construction site where workers in different physical locations require access to information and colleagues.

Some researchers may claim that these models do not comprise other important aspects of mobility. A general notion is that there is more to mobility than just the geographical movement of people and artifacts enhanced by modern ICT.

> "However, in order to appreciate a larger background of the emerging debates on mobility, we need to go beyond such a confined and functionalistic understanding of mobility and to capture various dimensions of mobilization of our social interaction" (Kakihara and Sørensen 2002, p. 10).

What makes mobility and mobile computing so complex, is the fact that we do not necessarily refer only to persons as mobile. Also artifacts have mobile features, not only new technology such as mobile phones and handheld devices, but also medical journals and other paper documents (Luff and Heath 1998). While Kristoffersen and Ljungberg (2000) in a way black-box the environment into social and physical surroundings, other researchers choose to focus on exactly these matters.

Various taxonomies of mobility have been proposed, and Kakihara and Sørensen (2002) confine mobility to *spacial*, *temporal*, and *contextual* mobility. Spacial mobility do not only refer to the immediate aspect of geographical movement of people, but also to the mobility of objects, symbols and images. Temporal mobility refers to how people interpret and structure their time. Contextual mobility refers to the way ICT influence contextuality in interaction. For example, interaction may be labeled unobtrusive or obtrusive, and ephemeral or persistent. A message on a Post-It note may be characterized as unobtrusive-persistent, while an buzzing alert message on the mobile phone can be obtrusive and ephemeral. An example of the dilemma of contextual mobility is present in this thesis. When the mobile phone is chosen as the device for the CSCW-application, one should be aware of the different roles the phone plays. Receiving a call while registering information in the application may be far more obtrusive than receiving a call while writing an SMS. This is further discussed in chapter six.

There are also a number of different motivations for being mobile and support mobility. Some, like blue-collar workers, have always performed assignments on different physical locations. Others have been tied to a stationary workplace, which has been regarded as inflexible.

> "The new working life is an especially interesting field when it comes to flexibility, since its' prophets brag about "new work" being more flexible than "old work". An increasing number of employees are loosening their chains to their desktops. Thanks to wireless information technology and a placeless Internet, they can work at any place" (Eriksen 2003, my translation).

However, a lot of these new nomadic employees report that they feel less flexible than before. How come? Hylland Eriksen suggests that while employees experience an increase in spacial flexibility, the temporal flexibility decreases. Time has become the limited resource, because breaks and time-offs are filled with work-like activities. Others also point to this potentially negative aspect of mobility, the blurring of borders between work and personal life (Gant and Kiesler 2002). Thus, to the already complex interrelation of mobile persons, artifacts and information, new parameters of time and space are added.

Julsrud et. al. (2002) refer to mobile work as nomadic work: "*Nomadic work* is used in this report as a term for work performed away from the company's own offices and away from the employees' own residence" (*ibid.* p. 3). According to their report, a growing number of employees, which earlier were stationary, can now be labeled as mobile or nomadic. A key term in this development is flexibility, an "important ingredient in several modern strategies of business development" (*ibid*, p. 2).

Concerning blue-collars, it can be argued that they have "always" been mobile, due to their spacial, geographical mobility. The question should not be whether they can become "more mobile", but mobile in other ways, by introducing ICT for cooperative matters. However, the introduction of ICT and more cooperative work routines make an organization more complex and challenging. The challenges are found particularly in organizations that "turns mobile", because of the increased complexity of a nomadic environment. "As the organizations become mobile, the need for awareness of others and what they know becomes increasingly important" (Lyytinen and Yoo 2001, p. 9). Lyytinen and Yoo (2001) define nomadic information environments as "a heterogeneous assemblage of interconnected technological and organizational elements, which enables physical and social mobility for computing and communication services. (p. 3). Note the introduction of another kind of mobility, *social* mobility, which refers to how persons easily can change social settings and roles, still being supported by technology and services. The mentioned complexity creates research challenges for Information Systems researchers. Lyytinen and Yoo outline research issues in nomadic information both on the services and infrastructure layer, on individual, team, organizational and inter-organizational levels. This thesis will deal primarily with design of services on a team and individual level.

2.2.1 CSCW and mobility

Considering the multi-faceted nature of CSCW, it would be strange if not a large amount of research was directed at mobility and mobile work. Wiberg and Grönlund (2000) define mobile CSCW to be "working together at various sites with the use of mobile IT" (p. 2). Colleagues may be physically separated, and individuals move between several locations. They outline five research areas of mobile CSCW, which include social aspects of how to build and sustain communities and social groups. Further, working and sharing knowledge at a distance require coordination and meeting-points for coordination, because "mobile work is remote, decentralized, and highly individual rather than stationary, centralized and shared common task related" (*ibid.*). Coordination of customer services can also be a challenge if several mobile workers are involved in helping a customer.

An experiment of people using mobile technology to support maintenance of bicycles showed that they improved performance when it was possible to communicate with a remote expert (Kraut, Miller, and Siegel 1996). However, the performance results did not improve by the appliance of better tools for communication. That is, the use of sound versus video *and* sound did not make any difference other than the form of communication. "We found no evidence that differences in communication technology influenced success in collaboration" (*ibid*, p. 64). This article is interesting in the study of blue-collars, because some of the interviewed blue-collars expressed a wish for the possibility of receiving help and advice when they are working "in the field".

2.2.2 Studies of nomadic workers

Since this thesis treat with mobile blue-collar workers and salesmen, it is interesting to look at other studies of the same problem domain. Julsrud et. al. (2002) have studied both blue-collars and salesmen. In the nomadic environment of blue-collars, they have interviewed a carpenter and three electricians. The carpenter runs his own company, thus he has many different roles and work tasks, both administrative office work, carpentering and customer service. His work is located to his office in the daytime, his home-office in the evenings and visits to the assignment sites during the day. Because of this mobility and different working sites, he consequently mails himself frequently in order to access it at home. As he explains; "I definitively should become more mobile, I'm already a little bit on the way though" (*ibid.*, p. 21, my translation). What is interesting by this statement is that he implicit connects "mobile" to the use of ICT. While a large part of his working day already is made up of driving, becoming more mobile means having access to information anywhere at any time.

Electrician "K" worked at the time of the study primarily as foreman on a construction site, rehabilitating bathrooms in an apartment building. "The absence of routines for efficiently sending hour lists and invoices forces K to move between several sites, that is the construction site, the main office, the storage, and to private customers" (*ibid.*, p. 25, my translation). In worst case scenarios, "K" drives approximately 60 kilometers in one day.

In the study of salesmen, the patterns of mobility is comprised to a local area. The salesmen do not possess an office, and they are highly mobile within a certain geographical area. They move between a fixed number of grocery stores and one visit at the head office about once a week.

A common feature of the work of both blue-collars and salesmen is the need of coordination. Their pattern of movement, or mobility, is defined as ambulating, that is they move from place to place. The need of coordination and cooperation becomes evident when a number of workers are dependent of others at different locations.

2.3 Designing CSCW-applications

So far, terms of CSCW, cooperation, and mobility have been presented and discussed. The next step is to see what the literature says about designing CSCW-applications for mobile cooperative work. A common notion is that designing CSCW-applications poses other challenges than traditional development of single-user applications. "Designs that are good for individual work often hinder group work, and designs that support the group often restrict the individual's interaction with the application"(Gutwin and Greenberg 1998, p. 207). However, these challenges are most present in the design of synchronous distributed systems, where users have shared workspaces. In this thesis, the application will have asynchronous features, thus the approach of Gutwin and Greenberg will not apply fully in this context.

The term *groupware* has almost become synonymous with CSCW, because a lot of effort has been put into studies of groupware, applications or computer systems that may support people working in groups. “The goal of groupware is to assist groups in communicating, in collaborating, and in coordinating their activities” (Ellis, Gibbs, and Rein 1991, p. 40). In the same way as the definition of CSCW in general creates controversy, so does the definition of groupware; what should be included or not? Some consider most multi-user software, such as large databases and version control systems, to be groupware, while others limit groupware to systems that consider different roles and communication needs in a group (Grudin 1994a). In this thesis *groupware*, *CSCW-application* and *applications supporting cooperative work* are used interchangeably despite possible variations in the definition of these terms.

Being such a multidisciplinary field, it comes naturally that CSCW has often become an arena for discussions between traditionally opposing research philosophies. Often, the focus of researchers are *either* technological *or* ethnological. Grudin (1994b) stresses the importance of making a shift from a technological perspective to a work perspective. “Developers need sophisticated understandings of prospective users’ workplaces. Working with representative users whenever possible is standard advice for developing interactive systems” (p. 98). He outlines eight challenges for groupware developers, which are challenges based on psychological and social issues, not technological. The eight challenges are here presented briefly without a deep discussion. In connection to each point, Grudin also compares these to single-user applications, organizational Information Systems and he gives advice on how to address the problems. The problems will be more thoroughly discussed in the analysis chapters.

First, there is a considerable risk that individual users of groupware do not perceive a personal benefit from using the application. Cooperation as a collective activity (Bødker 1991) supported by such an application will consequently be at risk. Second, groupware is dependent of a critical mass to be useful, that is, if not enough workers use the application it looses its intention of supporting cooperation. Third, groupware may disrupt social processes, and this is treated more extensively by Perin (1991). Fourth, exception handling and improvisation is important features of group activities, and groupware may fail if it does not accommodate such ad hoc-situations. Fifth, even though functionalities that support group processes are infrequently used, it requires "unobtrusive accessibility and integration with more heavily used features" (Grudin 1994b, p. 97). Sixth, generalizations and evaluations of groupware is highly problematic, and makes it hard to learn from experience. Seventh, one should not rely on intuition in multi-user environments as one often does in the development of single-user applications. Developing groupware requires the participation of a range of different users. Eight and last, groupware requires a careful adoption and implementation process.

As Grudin's (1994b) third point stresses, groupware may lead to disruption of social processes. Perin (1991) claims that the diffusion and adaption of technology depends on social and cultural dynamics within organizations, and that the success of a system is not always due to the fulfillment of users' needs but to their expectations as well. She introduces the concept of *social fields*, which are "semiautonomous and self-regulating human associations that regularly appear within established institutions and organizations" (*ibid.*, p. 76). Designers should be aware that groupware supports such invisible networks, while managers often regard social fields with suspicion and discontent. One example of social fields are *organizational back regions*, where employees are not supervised or controlled. "When people work in remote offices or at home, they too are susceptible to similar managerial suspicions" (*ibid.*,p. 78). Thus, computer systems that create and support social fields, such as groupware may do, may very well become threatening to managers of companies and their need of organizational control. In many cases, they are also the ones who decide whether to incorporate a computer system. Breaking their expectations will make it unlikely that they invest more money in such a system.

Orlikowski and Iacono (2001) criticize the IS research community for not giving IT artifacts enough attention. They categorize articles in IRS[3] during the 1990s into five perspectives; *nominal*, *computational*, *tool*, *proxy*, and *ensemble* views. While the nominal view, dealing with technology as an "omitted variable" (*ibid.*, p. 128), represents 25 percent of the articles, the ensemble view only represents 12.5 percent of the articles. There are four different variants of the ensemble view, but they all deal with "the dynamic interactions between people and technology - whether during construction, implementation, or use in organizations, or during the deployment of technology in society at large" (*ibid.*, p. 126).

[3]Information Systems Research: http://isr.katz.pitt.edu

2.3.1 Scenario-based design

"Designing applications by scenarios is in no way an exact science" (Hjelm 2000, p. 33). This can make many scientist discard such an approach, but for a designer scenarios are "an invaluable tool when you are trying to understand the situation of the user, as you plan the design and implementation of an application" (*ibid.*, p. 33). *Design* was brought into the software development "in order to ensure that [...] *software works for people in a context*" (Bardram 2000, p. 237, author's emphasis). Later, various approaches to design have emerged, such as user-centered design and participatory design, but common for most of these approaches is that users have a prominent position (Kyng 1995). A number of design techniques have been developed under the label of cooperative design, which stress the importance of involving different groups with different competencies in the activity of design. Different methodologies may be applied in the design of software. Kyng (1995) outlines a strategy of cooperative design. First, the organization and work must be thoroughly studied, and described in work situation descriptions and work situation overviews. The purpose of the descriptions and overviews are to articulate and discuss problems and bottlenecks. In this thesis this corresponds to the case studies for eliciting requirements, and the proceeding analysis of the empiric material. Using Activity Theory in detecting potential breakdowns may corresponds to the "bottlenecks". Second, use scenarios, mock-ups and prototypes are developed in parallel, based on descriptions and overviews. "Use scenario indicate how computer support and (or) changes in work organizations may improve upon work situations" (Kyng 1995, p. 97).

A problematic issue concerning the use of a cooperative or scenario-based approach to design in this thesis is the requirement of user participation in such design. "It is [...] crucial that end users and developers cooperate in developing the use scenarios" (Kyng 1995, p. 100). In this thesis, end users have been practically unavailable for such purposes, and that is not a favorable situation. One answer would be to discard the use of scenario-based design. However, the answer in this thesis is to describe a scenario from a developers view, founded on the study of blue-collars and salesmen, and let others judge it from their viewpoint. It is possible to justify this based on the unfixed features and broad definition of a scenario:

> "The defining property of a scenario is that it projects a concrete description of activity that the user engages in when performing a specific task, a description sufficiently detailed so that design implications can be inferred and reasoned about. Using scenarios in system development helps keep the fu-

> ture use of the envisioned system in view as the system is designed and implemented; it makes use concrete - which makes it easier to discuss use and to *design* use" (Carroll 1995, pp. 3-4, author's emphasis).

Bardram (2000) adds to this view: "Despite their popularity, there is no general accepted definition of what a scenario is, what it should entail, or how it should be used" (p. 239). While scenario-based design has often addressed single-user systems, Bardram gives an account of collaborative scenarios as scenarios that try to capture "the overall design of a computer system by describing collaborative work activities that are to be supported and/or affected by the future computer system" (*ibid.*). Focusing on activities, scenario-based design may also be another argument for using activity theory.

2.4 Summary

In this chapter, theories on cooperative work and mobility have been outlined in relation to the CSCW research field. Activity theory is presented as the chosen "glasses" to study mobile cooperative work through. The theories constitute the backdrop of the discussion related to the first problem statement of analyzing mobile cooperative work. In connection to cooperative work the term groupware has also been introduced as software to support cooperation. This will be regarded in the discussion of the second problem statement of eliciting design requirements.

Terms presented in this chapter will appear in the following chapters. In the next chapter, technology that supports mobile cooperative work will be presented. In chapter four, arguments for combining Activity Theory and case studies are presented, and scenario-based design is discussed further. Chapter five, six and seven contain analyzes and discussions based on theory presented in this chapter.

Chapter 3

Mobile computing

This chapter is the more technological-oriented approach to mobile computing in this thesis. While the term can embrace both technological and contextual aspects, this thesis refers to mobile computing from a technological perspective. A technological definition of mobile computing is "computing using a device that can communicate through a wireless channel" (Chlamtac and Redi 2000, p. 1175). Mallick (2003) also attaches "mobile" to physical devices:

> "Mobile is the ability to be on the move. A mobile device is anything that can be used on the move, ranging from laptops to mobile phones. As long as location is not fixed, it is considered mobile" (*ibid.*, p. 4).

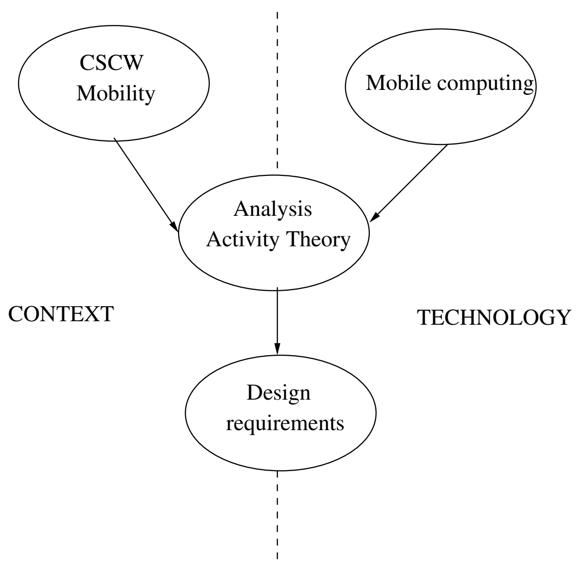

Figure 3.1: Theoretical approach

However, he acknowledges that "the definition of mobile and wireless varies from person to person and organization to organization" (*ibid.*). As the previous chapter should suggest, there is more to mobile computing than only physical mobile devices, and technological approaches often lacks an understanding of contextual aspects of mobility (Orlikowski and Iacono 2001). Figure 3.1 displays the theoretical approach in this thesis. Both contextual and technological aspects are united in the analysis, considering both aspects. The result of this analysis, the design requirements, deal with issues from both a technological and contextual perspective. Keeping this in mind, the previous chapter will serve as a backdrop in the examination of technological issues. This means that the interesting matter in this chapter is technology and devices that may support mobile cooperative work, and how applications that these devices carry are designed.

Technological improvements are the foundation for enabling mobility. "Advances in wireless networking technology have engendered a new paradigm of computing, called *mobile computing*" (Forman and Zahorjan 1994, p. 38, author's emphasis). However, the rapid development of networks and devices, and the lack of widely accepted standards have made mobile computing as

> "diverging as the domain of desktop computing was some twenty years ago. Just like in the early days of home computing, when computer manufacturers enforced incompatibility even within their own range of devices, there are numerous excluding alternatives for the mobile user" (Magerkurth and Prante 2001, p. 16).

In this way, technology itself becomes a threshold for developing CSCW-applications. Magerkurth and Prante (2001) claim that in the context of CSCW-applications the lack of cross-device availability of software and data exchange is especially harmful, because mobile CSCW is often dependent of using multiple different devices. If mobile computing should be able to offer functionality to CSCW, "it is essential to provide a seamless application infrastructure on all of the devices in a CSCW setting" (*ibid.*, p. 16).

While they doubt the adequacy of Java to solve this challenge, Java™2 Mobile Edition is used as a tool for developing the prototype in this thesis. An argument presented for using J2ME™ and Java™ is, opposing Magerkurth and Prante (2001), that the Java technology addresses various devices, and thus is a cross-device solution. However, this thesis is not focused on comparing J2ME™ to other competing technologies, so a discussion on which technology that is best suited for CSCW-purposes will not be treated. Since the J2ME^{TM} is used as a tool in this thesis, a theoretical account of the features of J2ME^{TM} will be given in the last part of this chapter.

3.1 Application

The model of Kristoffersen and Ljungberg (2000), presented in figure refsom:Kris, will serve as a point of departure in the discussion of mobile ICT. According to their model, the "technological parts of mobile IT use are called application. The three components of the application are technology, data and program" (p. 151). In the following sections, the technology and program concepts are elaborated, while the concept of data is practically omitted.

3.1.1 Technology

Technology in this context, and following the ideas of Kristoffersen and Ljungberg (2000), is the "carrying platform, or medium of the application" (p. 151). A reasonable understanding of this statement and a sensible limitation of mobile technology would be to concentrate on handheld devices of ICT, basically PDAs and mobile phones. Other mobile ICT-tools, such as laptops, handheld PCs etc, will not be considered in this thesis. However, one should keep in mind that using mobile CSCW-systems must include the use of stationary desktops as well. In addition, other technological preconditions of mobile ICT such as networks and servers will be mentioned.

For a device to be wireless, it must be able to transmit voice or data over radio waves. "It allows workers to communicate with the enterprise data without requiring a physical connection " (Mallick 2003, p. 4). During the work on this thesis numerous new versions of mobile phones and PDAs have been released, and new services and applications are frequently launched. Thus, this will be far from a complete account of the field, it would be impossible to keep track of all the news. However, some basic elements must be present in developing wireless applications and services.

The main hardware components in a mobile computing architecture are servers, databases and mobile clients that can communicate, and a network infrastructure that transport the communication wirelessly. Hardware is a very decisive factor when it comes to developing mobile solutions, because the technology so far has been, and still is, immature compared to stationary computers and networks that connect these. The server side does not pose any big challenges in this respect, because the capacity overrides both network and client capacity when it comes to throughput of bytes, memory and processing. Potential mobile clients to study in this thesis are mobile phones and PDAs:

Mobile phones

It is not long since mobile phones were designed for voice transmitting purposes only, and still the core feature of this artifact is talking to other people. However, the design of new services for mobile phones is one of the key drivers behind the rapid expansion of the mobile market. Technological advances have opened the way for services and features such as SMS, MMS, WAP[1], Java, Bluetooth, color displays and games. "Mobile phones are becoming more data-centric and evolving into what the industry calls "smartphones""[2] Opera has developed a web browser for mobile phones. These smartphones are hybrids of mobile phones and PDAs.

The Personal Digital Assistant

Originally, Personal Digital Assistants (PDAs) acted as mobile databases, carrying information of phone numbers, calendars with schedules and to-do lists (Fox and Verhovsek 2002). While mobile phones and PDAs have converged regarding these functionalities, PDAs are supporting a much larger range of third-party applications, such as word processors, spreadsheets and games. As with stationary PCs, PDAs come with different operating systems (OS). The three leading operating systems today are: the PalmOS[3], Microsoft CE[4], and the SymbianOS[5].

3.1.2 Choice of device

Different matters have been considered in the selection of a device for the prototyping. PDAs have some obvious advances compared to mobile phones, such as larger displays, larger memory and storage capabilities, and better access to existing software. These are features that are valuable in the development of a smart client solution, presented in the next section. However, these are the restrictions that are interesting to explore in the use of mobile phones. For example, may the small displays of mobile phones make elicited requirements impossible to meet,

[1]Wireless Application Protocol
[2]http://www.opera.com/products/smartphone. Accessed May 10th 2004.
[3]http://www.palm.com. Accessed May 10th 2004.
[4]http://www.microsoft.com/windowsmobile. Accessed May 10th 2004.
[5]http://www.symbian.com. Accessed May 10th 2004.

and the restrained performance capabilities may affect the architectural design.

An important issue is also to examine the mobile phone as a platform for different categories of groupware. Poltrock and Grudin (1999) identify three categories of groupware which are; purposes of communication, information sharing, and coordination. In developing applications for mobile phones, one should keep in mind that these purposes may become conflicting when they share the same resource. For example, the main purpose of a mobile phone is synchronous communication, and blue-collars in the case studies report that their mobile phones are mainly used for verbal communication. One would imagine that a busy blue-collar entering information of a job in his work coordinator application on his phone, while he during this task receives calls on the same device, would experience this situation as troublesome. This will be discussed in chapter seven.

3.1.3 Program

"A program processes data" is Kristoffersen and Ljungberg's (2000, p. 151) short definition of what also will be referred to as software in this thesis. The program is also by some understood as the application. Mallick (2003) gives this definition of a mobile application: "For an application to be considered mobile or wireless, it must be tailored to the characteristics of the device that it runs on" (p. 4). However, applications might of course be wireless and not mobile, alternatively mobile and not dependent of a wireless connection. Many applications developed for laptops and PDAs do not require a wireless connection. Data may be stored on the device, and synchronized using fixed connections, for example a USB-cable or a synch-station in the office or at home.

Mobile applications are often categorized by their use (Mallick 2003). m-Commerce (mobile commerce) solutions are applications and services for commercial purposes such as mobile banking, shopping and advertising. m-Business solutions, as the name suggests, are applications and services for enterprise purposes, especially providing secure access to business related data from any location. This includes mobile office, transportation and logistics services, and field services for mobile workers. Another large category of mobile solutions are applications for entertainment, for example Java games for mobile phones (Fox and Verhovsek 2002).

Smart client architecture

Choosing the architecture of an application, how it is built and organized, is an important design decision. The architecture and software must meet the application's level of complexity by offering the right level of capabilities (Mallick 2003). *Thin client applications* are applications that need no other software than an Internet browser, which can process and display the content received from the server. In the world of desktops such browsers can be Windows Internet Explorer or Netscape Navigator. In the world of mobile phones, the WAP standard is the most well-known browser, and Opera Software has also released an edition of their browser for mobile devices. In a thin client architecture all of the application logic is executed by the application servers. The apparent consequence of this, and a negative one if the user is unable to connect to the network, is that users must be on-line to be able to use the application. A positive consequence is that no software has to be deployed in order for users to adopt such applications.

Increasing the level of complexity and capabilities in the application architecture spectrum, *smart client applications* are software that is specifically developed for a device, and consequently this software has to be deployed on these devices (*ibid.*). This may be considered a negative feature of smart client applications, but it is weighed up by a number of positive features. A smart client application has the ability to store data. This means that users are not dependent on connecting to a network for registering data. The performance and speed of an application may also increase with the possibility of not having to connect to the server every time the application is used. Furthermore, the amount of data transferred wirelessly can be reduced, because the synchronized data are more specific than the extra bundle of data that comes with a thin client application (e.g. HTML-code). The synchronization of data in smart client architectures are also possible via wired networks, for example using a USB-cable between a PC and a mobile phone, or using synch-stations. While Mallick (2003) partly discards the use of mobile phones as smart client devices, a lot of mobile phones today may still support features of a smart client architecture. This is one of the issues that are explored in the prototype.

3.2 J2ME^{TM}

Since Java^{TM}2 Platform, Micro Edition (J2ME) is used as the tool for developing a prototype, the technology will be shortly presented in this section. The prototyping is presented in the next chapter. The J2ME^{TM}-

standard is developed by Sun Microsystems[6] in joint effort with large telecom- and IT-companies such as Nokia[7], Sony Ericsson[8] and Siemens[9]. So far, J2ME™ has become widely known as "Java games", since a lot of effort is put into developing and marketing games for Java-enabled mobile phones. Inpoc[10] has sold 250,000 Java games in Norway in one year. The market of services as ring-tones and mobile games has grown with NOK 200 mill from 2002 to 2003[11] At the same time, J2ME™ is also intended for development of utility services for a professional market. A lot of interesting issues may be studied in the meeting between the fast-moving, dynamic environment of mobile computing, and the preferably steady, predictable work environments of blue-collars.

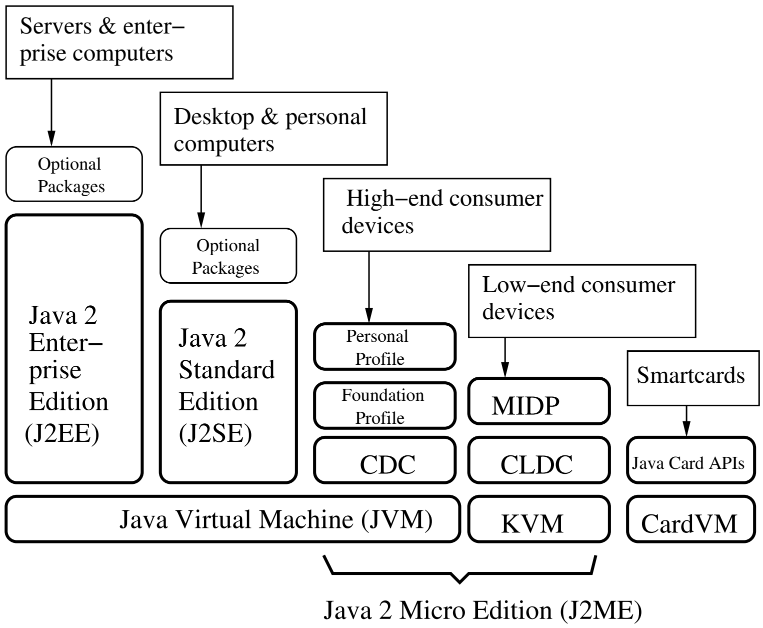

Figure 3.2: Java 2 Platform editions

Figure 3.2 is an overview of the different Java™2 Platform editions. The J2EE and J2SE have become popular and widely employed in IT-business solutions, especially on the server side and Internet applications. An important reason for the success of Java is its philosophy of platform

[6]http://java.sun.com/j2me/. Accessed May 10th 2004.
[7]http://www.forum.nokia.com/main.html. Accessed May 10th 2004.
[8]http://developer.sonyericsson.com/site/global/docstools/java/p_java.jsp. Accessed May 10th 2004.
[9]http://www.siemens-mobile.com/mobile. Accessed May 10th 2004.
[10]http://www.inpoc.no/index.vsp. Accessed May 10th 2004.
[11]Dagens Næringsliv, "Ringetoner og bilder for 600 mill.", January 26th, 2004, In Norwegian.

independence, "write once, run everywhere". Though things do not work as easily in practice as in the ideal world of Java, one argument for applying Java in this thesis is the requirement of seamless solution for different devices. For example, in the development of the server side of the prototype in this thesis, an important requirement is that information is accessible both wirelessly from a mobile phone or from a stationary computer via the Internet. In the same manner, the J2ME^{TM} code produced for a mobile phone should also be able to run on a PDA.

> "Rather than developing a native application that will work only on the targeted operating system, you can develop your application using Java and be able to target a variety of operating systems without having to rewrite the application" (Mallick 2003, p. 168)

However, this is too good to be true, because the large variety in the performance and features of devices means that applications are not fully portable. Still, Mallick claims that "Java technology will become a viable option for creating sophisticated, data-driven smart client applications" (*ibid.*).

3.2.1 Configurations

Figure 3.3 gives a hint of the enormous differences in capacities between mobile phones, PDAs and PCs. Some numbers are the minimum of what is required for the different J2ME^{TM}-profiles to be able to run. In the figure mobile phone and PDA are followed by the terms CLDC and CDC. These are names of J2ME^{TM}-*configurations*. The primary goal of a configuration is to "define minimum requirements for memory, language support, virtual machine and runtime libraries" (Giguère 2000, p. 90). The reason for doing this is to horizontally categorize or group a number of devices, so that device manufacturers and content providers know what to expect of available devices of the same category.

Dealing with mobile phones, the interesting configuration is the CLDC, Connected Limited Device Configuration. While the CDC, Connected Device Configuration runs on a Java Virtual Machine and addresses machines with a fairly large memory and processing power, the CLDC runs on top of the KVM, and is designed for the low-end consumer devices.

3.2.2 Virtual Machines

A Java Virtual Machine is a runtime environment for Java programs, which normally runs on top of an operating system. The K Virtual

	Mobile phone (CLDC)	PDA (CDC)	PC
Memory RAM	- 128kB[1] for running Java - 32kB[1] for runtime memory allocation	- 512kB[1] for running Java - 256kB[1] runtime memory allocation	512MB
Storage	1MB	64MB	< 40GB
Screen	96x54[1] pixels	3.5”	17”
Network connection	128Kbps[2] GPRS	128Kbps[2] GPRS	704/128Kbps ADSL
Clock speed	25MHz[1]	266MHz	2.4 GHz
Instruction set	16/32bit	32bit	64bit

Figure 3.3: Comparing devices
[1]Minimum requirement.
[2]Highly dependent on network traffic.

Machine is a virtual machine especially designed for small resource-restrained devices, such as mobile phones. Due to its limited memory capacity, measured in kilobytes, the “K” stands for “kilo”. The memory budget required by a KVM ranges from a minimum 128 kilobytes up to a few hundred, while the typical implementation requires 256 kilobytes. This memory is shared between the runtime heap space for applications (minimum 32 kilobytes), the virtual machine itself (60-80 kilobytes) and the rest of the memory is reserved for class libraries.

3.2.3 Profiles

While configurations horizontally addresses a group of devices, the profiles vertically addresses one device family, for example mobile phones, washing machines or electronic toys (Riggs, Taivalsaari, and Vandenbrink 2001). The MIDP, Mobile Information Device Profile, is designed for mobile phones and other two-way communication devices. Thus, this is the profile that is used in the prototype of this thesis.

3.2.4 Programming constraints

A considerable challenge in programming applications for mobile devices is the limited capacity these devices have (Allin 2001). In programming applications for stationary PCs, code optimization is becoming less crucial for the performance of the program, because of the power of PCs.

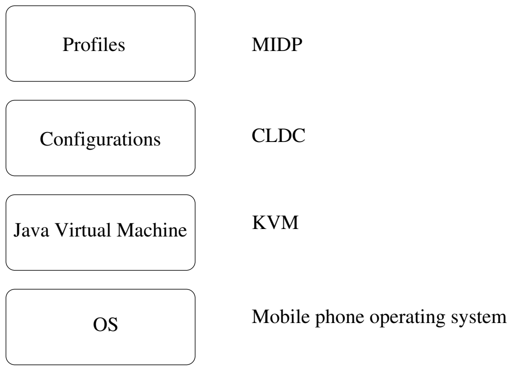

Figure 3.4: Layers of a J2ME^{TM}-application

Optimizing J2ME^{TM}-code will often break with other programming principles. Some of the dilemmas are outlined by Allin (2001). First, optimization often conflicts with code clarity, maintainability and portability. For mobile phones, it may be purposeful to make code as short as possible, thus using short "cryptic" names on variables and methods. Each letter in the name of a class or constructor and in public methods or public variables adds an additional byte to the execution code (Mallick 2003). However, this makes it hard to maintain the code, and in an CSCW-application that may require substantial maintenance, code should be written clear and understandable. Second, "improving start-up time and execution speed are often in conflict" (Allin 2001, p.250). As the case studies revealed, the fastness of an application is important for users in blue-collar environment. But should the user wait for an application to start up, or is it better to let him wait once the application is running? This is particularly a question in the establishing of the connection between the client and server. This can be done at once, shortening the time later in the transmission of data. However, if the user only will edit some data without transmitting them, using resources on the connection will be superfluous. Third, "improving performance is often in conflict with reducing memory" (*ibid.*, p. 251), for example in the use of caching as performance improvement. As mentioned earlier, memory is a very limited resource, especially in mobile phones. Allin points to the right design and architecture as the best solution also for optimizing performance of the application. It is important to design to interfaces first, then find out which implementations and algorithms that are right to use. Figure 3.4 sums up the different components. Being able to run a MIDlet, the device must have the MIDP specification implemented. This runs on top of the CLDC which also must be implemented. In order to run any Java class file, the device must have a Java Virtual Machine, in mobile phones often the KVM. At last, all of this run on top of an operating system (Fox and Verhovsek 2002).

3.3 Summary

This chapter is a technological approach to mobile computing, focusing on what Kristoffersen and Ljungberg (2000) call the application of mobile IT use. The application consists of technology, program and the data. Technology is here interpreted as the hardware part of the application, that is servers, the network infrastructure and mobile devices. The program is interpreted as the software part of the application, and J2ME™ is presented as a platform for developing software for mobile applications that supports cooperation.

J2ME™ is chosen as a prototyping tool, because it is a cross-device technology, which is purposeful in the development of CSCW-applications. It can be used to program applications for both PDAs and mobile phones. In this thesis the mobile phone is the choice of device for the prototype.

Chapter 4

Methods

This chapter presents the applied methods in the work of this thesis and reasons for employing these. The applied methods are case studies and prototyping, and these are presented and discussed in respective sections. The case study approach is one of many qualitative research methods, and the use of this method is discussed in relation to other potential qualitative methods to use.

The applied methodology should follow by the goals of the study, and the first goal has been to gain knowledge and understanding of ICT in nomadic work environments. At the same time, some methods require more resources than available, and otherwise potential methods would therefore be excluded. Thus, the applied methods in this thesis are both a result of what was wanted to discover and the existing limitations. In the presentation of qualitative research methods, other approaches are discussed, and reasons are given for why they are not used.

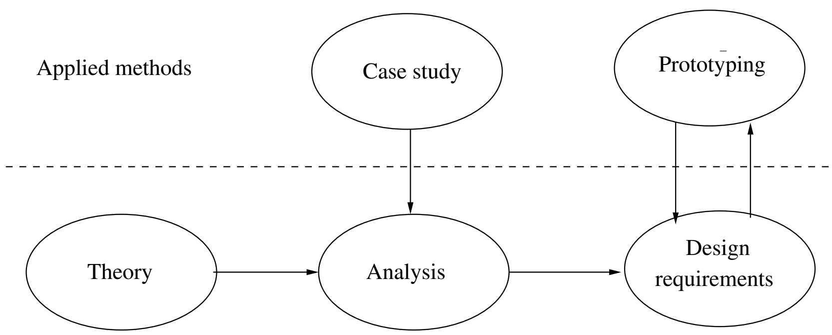

Figure 4.1: Methodological approach

Figure 4.1 summarizes the methodological approach of this thesis. As described in this figure, the prototyping is based upon the design requirements of the analyzed case studies and theory. The prototyping is used as a method to learn from and comment on the application domain of a potential system.

An important part of doing these case studies has been to elicit requirements for design of ICT for mobile cooperative work. By generalizing the results of these studies, the outcome should be advices and guidelines for designing CSCW-applications. Preferably, it should lead to generic application that can be used in various settings.

However, generalizability is one of the most difficult topics of qualitative research. Problems arise on many levels. For example, the selection of participants may be too small. When the differences in three blue-collar companies are quite big, one can only imagine the multiplicity of differences in one hundred companies. The interviewed managing director of the software company (see chapter five page 54), also stressed the importance of a large selection of participants when he explained that he had interviewed hundreds of blue-collars during one and a half year of preparations. As Guion (2002) points out, the validity of the data may increase with an increasing number of participants, called data triangulation. However, as Lee and Baskerville (2003) warn against making generalizations to other settings than the ones studied, this thesis does not attempt to predict features of other settings than blue-collars and salesmen.

4.1 Qualitative research methods

Qualitative research methods, as opposed to quantitative methods, were originally the result of social scientists developing methods for studying social and cultural phenomena (Myers and Avison 2002). These phenomena are seldom quantifiable, and require other research methods than the quantitative methods that have been predominant in natural sciences. The research settings are most often outside laboratories, and data may be collected from a number of sources:

> “Qualitative data sources include observation and participant observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher’s impressions and reactions” (*ibid.*, page 5).

Quantitative methods originate from the positivist research approach in natural sciences, but examples of such methods are also accepted in social sciences, e.g. “survey methods, laboratory experiments, formal methods (for example, econometrics) and numerical methods such as mathematical modeling” (*ibid.*).

The dualistic view of positivism versus interpretivism has been inherited in computer sciences as well. Mathiassen and Dahlbom (1993) describe these philosophies as hard systems and soft systems thinking. Being interested in human-computer perspective, scientists of Information Systems tend to value the interpretive approach the most. With its focus on work practices and *use* of ICT, this thesis adopts a soft systems perspective.

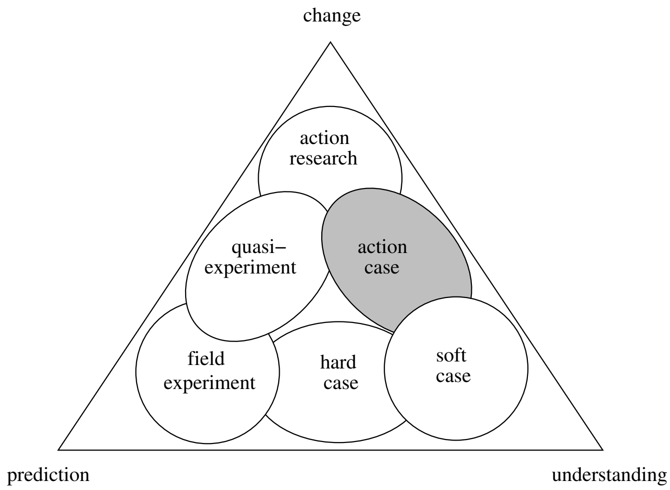

Figure 4.2: Research methods.

But there are also a number of different approaches to soft systems thinking as well, and a variety of qualitative research methods in the study of humans and organizations. Braa and Vidgen (2000) summarize Information Systems research methods in a triangle in figure 4.2, an IS research framework. They found the two-dimensional axis of positivist versus interpretivist approaches to be inadequate for research in organizational settings. The positivist approach' main intent is to predict outcomes through reduction, while the interpretivist approach seeks to gain understanding through interpretation. In organizational settings these approaches are not worthless, but "all forms of research conducted in the organizational laboratory carry with them an interventionary element" (Braa and Vidgen 2000, page 254), thus the "intervention should have the intention of changing the problem situation for the better rather than for the worse" (*ibid.*). The third point in this triangle is change, which represents an interventionary approach. The figure also displays the fact that few methods are purely categorical in their approaches, but they are inspired by various views.

As mentioned earlier, one focus of this thesis has been to gain *understanding* of blue-collar workers and use of ICT in their work. Thus, the approach is located to the corner of understanding in Braa and Vidgen's triangle, it is an interpretivist approach. To a small extent, this thesis also touches an interventionary approach, since it *suggests* changes in the studied companies in order to make work practices more effective.

However, the primary goal is to interpret, understand, and elicit interesting aspects in the existing case studies, not claim that these are features present in *all* similar environments. Lee and Baskerville (2003) also warn against making generalizations to other settings than the one studied. At the same time, the reason for studying several companies has been to compare them and find commonalities and differences between these, in order to be able to describe general features. Designing applications is also a process of trying to predict how a system will function in similar settings to the ones studied.

Positivist and reductionist methods such as **field experiments** and **quasi-experiments** can therefore be disregarded. These try to capture the laboratory setting in a real-life environment, by preserving properties of true experimentation such as multiple treatments, randomization and experimental control (Braa and Vidgen 2000). Besides being unable to answer the questions in this thesis, it would be impossible to find participants for such experiments in blue-collar companies.

That would also be the case in an interventionist approach. Although one case study regarded the implementation process of ICT in a company (described in chapter 5), we had no intent of making interventions or influence the process. This was neither the goal of the study, and the company would not allowed any intervention. If the thesis demanded an interventionary approach, **action research** would be an appropriate method. Theories are tested through intervention in the organization (*ibid.*). There are different approaches to action research, but often a relationship is established between researchers and participants, especially in participatory action research where practitioners act as both subjects and co-researchers. **Action case** is a research method proposed by Braa and Vidgen, and it is a hybrid of action research and case studies. Two reported research cases were initiated by case studies, and followed by more interventionist actions. They argue that the studies "were not "pure" interpretations since they contained an element of intervention, while the testing of the IS quality and priority workshop methods did not lead quite to the scale of change that one might expect in full-scale action research" (*ibid.* p. 265).

Having excluded both positivist and interventionist approaches, the remaining perspective is the interpretivist approach. **Soft case study** and **Hard case study** are two variants of case studies. Braa and Vidgen have found it purposeful to distinguish these types of case studies because of the diverging opinions among researchers in classifying the method to be closer to positivism or interpretivism. Data collections in case studies can be done in several ways, making it a versatile scientific method.

Ethnographic research is one interpretivist approach to case studies. Ethnography stems from anthropology, and originally the ethnographic approach was an participatory observation of a culture. In order to understand a culture, cultural codes and all of its hidden logics, the researcher will have to immerse himself or herself into being a member of the culture. The aim is to paint as rich a picture as possible of the culture or setting (Harvey 1997). Later, the view of the researcher as an unbiased observer has been strongly questioned, because both the scientist and the objective will interpret the situation and make selections as to what is important or not.

Grounded theory is also a methodology applied in for example CSCW, which aims to theoretically define a phenomenon through very systematic data collections and analyzes. Schmidt and Bannon (1992) propose grounded theory to uncover articulation work. This is normally work which is not regarded as important, but is in fact required for doing other work tasks. To reveal such work is often done through observations and not through interviews, because the interviewee will regard such work as unimportant and thereby forget to talk about it. One argument for employing grounded theory in this thesis, is the focus of secondary work of blue-collars, that is, everything they have to do in order to execute their primary work tasks and to cooperate. Much of these work tasks are based on articulation work.

Using the model of Braa and Vidgen (2000), the choice of method for collecting empirical material is the *soft case study*, though this will be referred to as case study. The conducted case study will be described more thoroughly in the next section.

4.2 Case study

Some important parameters were set when the applied methodology was chosen method. The most conspicuous one was the aspect of time, but it has also been a matter of access and resources. In most of the cases, the participants were willing to sacrifice a maximum of two hours for interviews and observations. Grounded theory and ethnographic research, for example, could therefore early be ruled out since these methodologies require more time than a couple of hours. Nearly all participants have appeared extremely busy, and would not have permitted a longitudinal study of their work. The limited access to organizations and workers also would have made experiments or action research impossible. Action research was also outside of my scope, since the scope was not primarily focusing on change in the organization, and strictly speaking, no company would let a student do interventionary studies in their surroundings.

The selection of the case study as method is not only based on the fact that other methods would seem inadequate or impossible to carry out, but also what this method has to offer, for example interviewing. "Qualitative interviewing is an extremely versatile approach to doing research" (Rubin and Rubin 1995, page 3). The case study approach seeks to:

1. define specific questions of study ahead of time;
2. emulate logical positivism in developing rival hypotheses and collecting external evidence bearing on these questions;
3. carry out fieldwork in a targeted fashion - i.e., focusing on the evidence deemed relevant and carrying out fieldwork in a time-limited manner (Yin 1989).

This approach was followed in the work of the case studies. Problem statements and preliminary hypotheses, defining the focus of the study, were established, and interview and observation guides were produced ahead of field studies. The limited time aspect, which earlier has been described as constraining, became an incitement for doing the fieldwork in a targeted fashion. The time "in the field" was therefore spent effectively.

4.2.1 Selection of participants

The initial part of the case studies consisted of doing research on existing services and software solutions. Apart from generic services such as SMS and MMS, there were few solutions specifically designed for the blue-collar environment. However, one software company that had developed such a solution, was singled out and contacted for an interview, further presented in chapter five. There were two reasons for choosing this company. First, it is market leading and it was hard to find any other similar company. Second, the interview might serve as a foothold for the further investigations, because the company would be an important source of knowledge on the topic of blue-collars and ICT. Hopefully, they would be able to provide us with references to people and companies that applied or had applied their solution. This would give a great opportunity to talk with people not only about the use of one ICT solution in particular, but also about the use of mobile technology and mobile work practices in general.

The succeeding participants were selected on the basis of some defined criteria. These criteria were presented to the managing director of the software company who provided references to matching companies. They were all users of the software solution, and interesting companies were:

- Experienced users. Companies that had applied the software solution for some years and could tell about their positive and negative experiences, and whether ICT had changed work practices.

- Similar users. Two companies with approximately the same number of employees and work routines, in order to compare companies that on beforehand would be similar. Would they regard and use ICT the same way?

- Unexperienced users. Companies that were planning, or were in the process of implementing the software solution. We wanted to know why and which incentives were dominant for using this technology.

- Negative users. Companies that had given up the software solution.

It can be raised questions to whether it was right to let the managing director make the selection of participants. He could have hidden motives for selecting the companies, for example only giving references to those who were positive to his product. This argument can be opposed by the fact that he also provided references to companies that stopped using the companies (the category of negative users). Unfortunately, none of these companies were willing to spend time on interviews, so what exactly their discontent was can not be answered here. The conducted case studies also showed that there were no companies that were extremely positive, nor negative, to the software solution. This should also justify the method of selecting participants in this thesis.

In addition, participants were also selected from other parts of and outside the blue-collar environment. This resulted in the interview of a construction site manager and people at the sales department in a brewery company. The purpose of this is means of comparison between blue-collars in different work environments, and nomadic workers in different professions.

4.2.2 Fieldwork

The fieldwork was made up of interviews and observations. Generally, it was a "one-time data collection effort - typically a short number of days - for every case to be studied, in which only post-hoc longitudinal data can be collected" (Yin 1989), which is one of two options according to Yin with regard to data collection. The collection of data in each company was conducted in a couple of hours after one or two visits to the company. After that, the companies were only contacted for shorter questions in case some details were unclear.

An aim was to consult more than one person in each company, trying to identify different opinions and views on both work practices and work-related ICT. As described earlier, the case studies were conducted by four students. Most interviews and observations were done by at least two persons. Each case was initiated by making an interview guide. "Prior to talking to the interviewee, the researcher prepares a handful of *main questions* with which to begin and guide the conversation" (Rubin and Rubin 1995, p. 145). These main questions always started out in a general fashion, such as "please, tell about your day at work", in order to gain knowledge of the setting in which the interviewee worked. Further, we would concentrate on more and more specific work practices, and last, focus on the use of mobile technology in work. We also prepared some follow-up questions, although these "pursue the implications of answers to the main questions" (*ibid.*, page 146). However, this is in some cases possible to predict, for example "in case he says that, we must find out whether...". During the interview we also asked *probes*, which are questions meant for clarifications of details and a way of deciding the level of depth of the interview (*ibid*).

After interviews and observations, recorded conversations were transcribed. If not recorded, each student made their own report based on notes and memory, and these reports were merged into one common report. Divergence in perceptions were discussed and sorted out, often by follow-up questions to the participants. The written documentation of these case studies is thus the basis for three other students as well.

4.3 Prototyping

This section presents and discusses the use of prototyping in this thesis. As pointed out before, using scenario-based design and prototyping may seem problematic when a clear aim of both these approaches is to serve as a communication tool between end-users and developers (Vonk 1990).

It is problematic because, in this thesis, the prototype is not developed in cooperation with potential end-users, but solely on the empirical material gathered in the case studies. However, it can serve as a point of departure for discussions with such users.

Another aspect is the fact that the focus of this thesis is not the implementation of a system in one *specific* company or organization, but rather give advices to design of more generic applications, or application packages (*ibid.*, p. 7). Thus, the role of the prototype as a communication tool diminish, since there are no specific end-users at hand. Other goals of the prototype must be found, for example the goal of *learning*.

> "System developers are advised to take advantage of the possibility of learning through experiments. The prototyping approach is a constructive response to some of the problems and weaknesses of the specifying approach" (Mathiassen, Seewaldt, and Stage 1995, p. 68).

Specification driven approaches have been successful in many application areas, but encounter problems in situations where requirements are hard to specify in advance (Boehm, Gray, and Seewaldt 1984). Specifying a system is hard when "the requirements analyst [...] has to deal with user responses of the form "I'm really not sure what I want, but I'll know it when I see it"" (*ibid.*, p. 290). This was also pointed out by the interviewed managing director of the software company, when he claimed that users do not know their own well-being, and that only 20-30 percent of the requirements were possible to detect by interviewing users.

4.3.1 The goal of prototyping

Prototyping has also other goals than being a communication tool. Budde et al. (1992) distinguish three kinds of prototyping related to different goals; *exploratory*, *experimental* and *evolutionary* prototyping. In an exploratory approach, the main goal is learning, both for developers and end-users.

> "Initial ideas are used as a basis for clarifying user and management requirements with respect to the future system [...] The developers gain insight into the application area and into the users' work tasks and the problem they face" (*ibid.*, p. 38).

In this thesis, exploring some of the elicited requirements from case studies by using a prototype, and try to learn from this, is a goal of using a prototype approach. In experimental prototyping, the main goal is evaluation, often focusing on "the technical implementation of a developmental goal" (*ibid.*, p. 39). Further, "[d]evelopers [...] are provided with a basis for appraisal of the suitability and feasibility of a particular application system". In this thesis, technical requirements are explored in the prototype. For example, when users claim that the application must be fast in use, 10 seconds according to the managing director, it is interesting to see how fast a mobile device connects to the remote server. If it takes one minute, it is easy to discard the prototype.

In an evolutionary approach, the main goal is accommodating change in organizations. This approach serves less as a tool, and more as "a continuous process of adapting an application system to rapidly changing organizational constraints" (*ibid.*, p. 39). This approach is not used in this thesis.

4.3.2 Selecting a prototype

According to Budde et al. (*ibid.*), prototypes can play different roles in a development project. A *prototype proper* in design "is used to illustrate specific aspects of the user interface or part of the functionality and thus helps to clarify the problem at hand" (*ibid.*, p. 36). A *breadboard* prototype is used to "help clarify construction-related questions facing the developer team" (*ibid.*). Thus, breadboards are often used for examining technical aspects of the future system. The prototype as a *pilot system* is used when the aim is to build the final system based on the prototype. While prototype proper and breadboard prototypes often are throw-aways, that is, they will not be used in the final system, the pilot system "requires a considerable more elaborate design" (*ibid.*).

Considering the fact that prototyping in this thesis is *exploratory* and *experimental* for learning and evaluation purposes, the prototype proper and breadboard are used in relation to these. In the prototype, examples of user interfaces (prototype proper) are given in order to show how an application will appear on a mobile phone. Technical features are examined (breadboard), for example programming storage and remote connection functionalities. In some sense it is also *throw-away* prototypes (Wieringa 1996, p. 302), since the prototype will not be implemented in a final system. However, it should be possible to reuse some of the produced code.

A prototype can be *vertical* and/or *horizontal*. A vertical prototype is a selected part of the system that is implemented completely, that is through all the layers (figure 4.3). This is often done in pilot systems. In this thesis, vertical prototyping is barely used, but exemplified in the development of the communication between the mobile client, the servlet, and the database. Horizontal prototyping designates the development on specific layers, for example prototyping the human-computer interface.

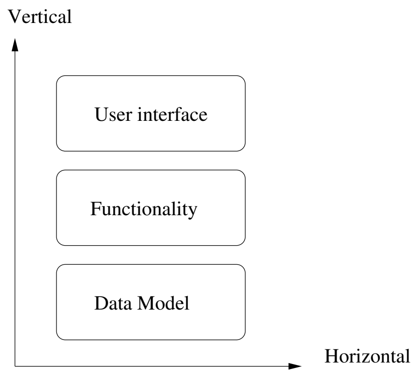

Figure 4.3: Software layers

4.4 Prototype development

The prototype was developed after the analysis of case studies, and based on scenarios elaborated from the analysis. In order to have an overview of the system UML[1]-diagrams; use cases, sequence diagrams and class diagrams were drawn. This was purposeful also by the fact that a fellow student assisted in making the prototype, in particular the server side programming.

The main focus of the prototype is the mobile client, thus a Java MIDlet, described in chapter three, was initially developed. The developing tool doing this has been the Java™2 Micro Edition Wireless Toolkit (WTK) and a text editor. The WTK contains a mobile phone emulator, which is used to test the application. This makes it fast and easy to see a result of the code directly on a mobile phone display. At any time, it is possible to transfer the result to a real mobile phone using a USB-connection. This is purposeful, since emulators often runs faster than real-life mobile phones, and the developer may be deceived by a fast emulator.

Initially, the interface was developed, by trying out different screens and testing the various possibilities that J2ME™ offers for making user interfaces. Different screens for different functionalities were also tested. After the development of screens, features connected to functionalities such as connection with the server, storage handling and representation

[1]Unified Modeling Language

of data were examined. In order to be able to connect to a server, servlets were also developed using Java^{TM}2 Enterprise Edition Application Deployment Tool and a text editor. These servlets also communicate with a MySQL database.

4.5 Evaluating a prototype approach

The goal of the prototype has earlier been defined as having learning purposes. In the evaluation the prototype, it has been interesting to see whether a prototyping approach can meet some of the criteria for good design of software, outlined in figure 4.5, as described by Mathiassen et al. (2000, p.178). This is proposed as a way of expanding the goal of the prototype approach in this thesis. While Budde et al. (1992) seemingly define learning as a goal in itself, this thesis tries to define a goal of this learning. Hopefully, what is learned through the prototyping is a prediction of how a future system will meet criteria of software quality.

Criterion	***Measure of***
Usable	The system's adaptability to the organizational, work-related, and technical aspects.
Secure	The precautions against unauthorized access to data and facilities.
Efficient	The economical exploitation of the technical platform's facilities.
Correct	The fulfillment of requirements.
Reliable	The fulfillment of the required precision in function execution.
Maintainable	The cost of locating and fixing system defects.
Testable	The cost of ensuring that the deployed system performs its intended function.
Flexible	The cost of modifying the deployed system.
Comprehensible	The effort needed to obtain a coherent understanding of the system.
Reusable	The potential for using system parts in other related systems.
Portable	The cost of moving the system to another technical platform.
Interoperable	The cost of coupling the system to other systems.

Figure 4.4: Classical criteria for software quality

4.6 Summary

In this chapter, the applied methods of this thesis is presented and discussed. This thesis is based on an interpretivist world perspective, and a qualitative research method is therefore best suited. Soft case study, referred to as case study, is chosen as the method to study the nomadic work environment of blue-collars and salesmen. The case studies consist of interviews and observations.

The prototyping is chosen as a method for learning purposes and for evaluation of the elicited requirements from the analyzed case studies. The prototyping is exploratory and experimental, and prototype proper and breadboard prototyping is used in the development of the prototype application. In evaluating the prototype approach, the goal of the learning is proposed to be an evaluation of classical criteria of good design of software.

Chapter 5

Case study results and analysis

This chapter presents the results of the case studies, and discusses these findings related to my problem definitions and the theory presented in chapters one and two. Terms and expressions will for the most part have been introduced in earlier chapters.

An important goal of this thesis is to give advice to the design of ICT that supports mobile cooperative work. Therefore, it is important to understand the work practices that ICT is supposed to support. Conducting case studies, and analyzing these, are used as a method for understanding these work practices, or *activities*, in nomadic work environments. In particular, the focus of the studies has been directed at work practices in connection with *cooperation*, *mobility* and *use of ICT*. The findings related to these three issues are treated in separated sections. First, focusing on cooperation, it is important to know how the employees cooperate, both vertically and horizontally. Second, focusing on mobility, it is important to understand how mobility and work practices influence each other, and how mobility influences cooperation. Third, understanding the existing use of ICT in these work environments can give recommendations for the design of future applications.

In the analysis of the collected empirical material, all of these issues are placed into the analytical framework of Activity Theory. Empirical results regarding cooperation, mobility and use of ICT are united in an activity system, and analyzed using the concepts presented in chapter two. In this activity system, four pillars, or categories are established as key factors in the design of CSCW-applications; *usability*, *technology*, *mobility* and *cooperation*. In the next chapter, more specific requirements within each category are outlined. These requirements are based on the identification of potential breakdowns in the activity system.

The chapter is structured in the following manner; First, a short presentation of the companies in the case studies is given. Second, the issues of *cooperative work*, *mobility* and *use of ICT* are presented and discussed. For the sake of clarity, the three issues are treated in separate sections, even though they are interwoven matters. Third and last, the analysis aims to unite the three issues in the theoretical framework presented in chapter two. Activity Theory is used as an analytical tool in this thesis. Case studies were conducted without choosing a specific theory in advance. The reasons for applying case studies and how this work proceeded is discussed in the previous methodology chapter.

5.1 Presentation of companies

The following companies were visited as part of the collection of empirical material for the thesis:

The software company[1] was established in 1985 and has 15 employees. The initial part of the case studies was an interview with the managing director ("MD") of this company. The motivation for doing this case was to gather opinions from a professional software developer's point-of-view, with a lot of real-life experience from mobile computing. Later, more information was added by a fellow student's interview with MD. The company is located in Oslo, and has developed a solution for blue-collar workers. The solution, "The Data Collector", was released in 1998, and has since become implemented in more than 300 companies with more than 2000 users[2].

The next three case studies consist of companies that are users of the Data Collector, and they were studied using the same approach. For example, approximately the same interview guide were used for all the cases. The "blue-collar companies", which they will be referred to as a common term, are fairly similar in size, and the work is organized around *assignments*. The motivation for these cases was the fact that these companies have hands-on experiences with an existing mobile ICT-solution. We would also be able to examine some of the claims that MD made, both regarding the Data Collector and ICT in blue-collar companies in general. The selection of participants are discussed in chapter four page 44.

The plumbing company has 17 employees, and they process between 50-70 jobs per week. The case started out with an interview with "Tom"

[1] Companies, persons and products will be referred to using pseudonyms
[2] January 12th, 2004

who is part owner, administrator and plumber. The company is an experienced user of Data Collector. Next followed an interview with two employees in the administrative staff. Some days later, we followed a plumber for a limited[3] field observation and an interview, we did a follow-up interview with Tom, and we had a conversation with five plumbers during lunch-break. Their customers are primarily private households, but assignments are also related to larger building projects.

The Electro Company A case consists of an interview with "Sven", the manager of the Service and Automation Division of the company. Next followed interviews with an electrician and an apprentice. The company is also an experienced user of the Data Collector. The division counts 65 electricians, and it is primarily organized around mobile service units. These are company cars operated by experienced electricians and equipped for difficult and varied tasks in connection with installations, rehabilitations and rebuilding of various kinds of constructions. Their customer-base consists of primarily public and private organizations and companies.

The Electro Company B is an enterprise with 28 employees[4], divided into two branches. Initially, we interviewed the managing director of the company before they had implemented Data Collector in their organization. Two month later, after the implementation, we came back to do a second interview. This time, we also interviewed to electricians, in order to know how users regarded their new tool. Hence, this was an unexperienced user of Data Collector. The timespan of their assignments range from a couple of hours to a full year, and their customers are enterprises and institutions. Some workers operate all over Norway.

The construction company has approximately 130 employees, and a turnover of NOK 350 millions a year. An interview was conducted with a construction site manager (CSM), who is head of the organization at project locations. The company does not use any mobile ICT-solution such as the Data Collector, apart from construction site managers and foremen who have been offered PDAs from the company, but this is on a voluntarily basis. The PDAs are used as personal organizers. The motivation for this case was to broaden the perspective of how blue-collar workers operate. While the three previous companies are smaller and assignment-based, that is, they carry out a lot of smaller service jobs on different locations, the construction company is responsible for large projects at the same location for a longer period. The focus of this case was to com-

[3]Followed during the performance of one assignment
[4]June 2003

pare the work practices in a project-based company with the practices in assignment-based companies.

The brewery case contains interviews with a sales manager and a sales planner, and interviews and observations of customer consultants. The motivation of this case was to collect information about nomadic workers other than blue-collars, and to investigate whether some features of the work of blue-collars also apply to salesmen. The primary work of blue-collars and salesmen are fundamentally different, but employees in both professions have to move around to different locations in order to perform their work. The sales manager is responsible for the sales of the company's soft drink in approximately 580 grocery stores[5]. He is in charge of 33 customer consultants.

5.2 Investigating cooperation, mobility and ICT

The first preliminary work hypothesis stated that there would be a high degree of cooperation and mobility in studied nomadic environments. In the case of mobility the hypothesis was supported, but the picture was not as complex as the theoretical part of this thesis suggests. Mostly geographical mobility was found, and there were distinct patterns of movement. In the case of cooperation, it exists in many forms, both vertically and horizontally, but it is much harder to find a distinct pattern. Some companies preferred a strong vertical, or hierarchical, organization of cooperative activities. Other companies gave workers more freedom to organize horizontally cooperative activities. While workers in the blue-collar companies were organized around assignments, workers in the brewery company were organized in teams, and the management stressed the importance of team-building. Even though workers did not report a personally strong team-spirit, workers were in this case more urged to cooperate horizontally than workers in blue-collar companies.

The second work hypothesis stated that blue-collars have a high threshold for adopting work-related ICT except for mobile phones. According to the findings in these studies, this hypothesis is only partly supported. This view is supported by the study of the Data Collector. The blue-collar participants in the case studies reported no generally negative judgments of this ICT solution. However, the management in all the companies had to a certain degree dictated the introduction of the system, and dictates also the use of it. Still, most blue-collars prefer to make notes on paper in addition to the Data Collector for security measures. In the brewery company, experienced customer consultants did

[5] June 2003

not consider their priopt system as very important.

Finding current ICT-systems that supported mobile cooperative work was not easily done, because there were not many solutions available. Primarily, the search for such systems was done on the Internet, in publications about mobile computing and in articles. One single solution was found that could match the criteria of supporting mobility and cooperation[6]. This may indicate that the need of such systems is not very much present, or that mobile ICT is not mature enough for building such systems. Data Collector is, according to the managing director (MD), primarily a mobile data collection tool. That is, there is not put much emphasis on the aspect of supporting communication and cooperation within businesses, at least not on the horizontal level.

> "This is a vertical solution in the sense of not horizontal, if you think of Outlook calendar, e-mails and such things everybody needs. In a vertical niche you make a solution for where the money originates in a value chain" (MD, my translation).

From the beginning, the Data Collector has addressed the core problems of blue-collar businesses, which MD considers to be the messy world of paper as the main source of communication and registration of information. The main idea behind this system is to digitally register the information where and when it occurs. This information may be registrations of hours and materials. A common work practice in blue-collar environments have been to register everything on paper. Even in the largest companies:

> "It is so primitive that you wouldn't believe it. There are post-it notes, pieces of paper, packing notes, it is an endless mess of paper that flows into an office where trained workers are supposed to transform it into money" (MD, my translation).

However, in the further development of Data Collector, the functionality of message distributing has been added, thus it may support coordination and cooperation. Supporting horizontal cooperation within blue-collar companies is not a primary target from a business perspective. The main reason for this is not that there is not a potential market for this. The interview with the software company revealed that so far they had not paid much attention to cooperative issues, mainly due to technological thresholds.

> "You run a company with maybe thirty service cars, and you are supposed to coordinate your employees as efficiently as

[6]Winter 2002/2003

> possible. If you combine todays' feature of Data Collector with maps as we will do now, positioning as the next move, in order to know where you are...It is a matter of an improved GPRS, because the location-based services today is not precise enough" (MD, my translation).

Thus, MD acknowledges the need for these kind of services, but he links the future development of these services to technological possibilities. Through user-forums and customer service, the company receives valuable feedback from users of the Data Collector. The MD responds like this to the question of horizontal communication requirements:

> "It is in our spec for direct peer-to-peer communication. Let's say I'm out and lacks some material, then today I don't have the possibility of browsing the storages of my colleagues' cars. But if you think of an intelligent use of SMS or SMS-like messages, then you can search for materials with descriptions and id-number, and a list of mobile workers is displayed. Then you send a request and you will have horizontal communication, and strictly speaking the office doesn't need to know about it because it matters only to people working in the field." (MD, my translation)

Some of the functionalities in the prototype of this thesis are based on such SMS-like messages that the MD describes here, and the use of it is described in the scenario page 96. So far, this possibilities has not been prioritized in the Data Collector, but enhanced technology broadens the possibilities and prospects:

> "We are working on it [horizontal communication possibilities]. It could have been made, but it isn't urgent, because if you want to make it efficient we don't want to use SMS, we want to use an on-line connection, I would guess 2004 is an appropriate time considering the use of GPRS and terminals."
> (MD, my translation)

In the next sections, an elaboration of the findings of cooperation, mobility and ICT in case study companies follows.

5.2.1 Cooperation in case study companies

All three of the studied blue-collar companies, that is, the plumbing company and the two electro companies, used the Data Collector. An interesting aspect to study was whether the ICT-system reflected the core challenges in these companies. For example, was supporting horizontal cooperation something that could wait, or was it a pressing matter. The studies showed that MD was right in his strategy of not implementing this cooperative functionality into the Data Collector. Though he may receive requests from users that wish that type of functionality, he probably would not have received the requests from our case companies.

The plumbing and electro companies

In the plumbing and electro companies, it would be relevant to find examples of cooperation that was supported by Data Collector and that might be supported by ICT in other ways. For example, assignments and secondary work may be coordinated and distributed to workers wirelessly via ICT. Workers "in the field" may acquire help from co-workers if they have troubles in performing a primary work task. Furthermore, sharing materials from each others cars may be an option. That is, if plumber A knows that plumber B is closer to him than the central storage, and he knows that plumber B's car contains item X which he needs, then it may be time efficient to borrow item X from B's car instead of going all the way to the storage.

In the plumbing company, no such traces of cooperation was found, that is, we could not find any examples of Data Collector supporting horizontal cooperation. Tom could tell that they used an older version of the system, and did not feel the need of upgrading, as they were content with what they had. As there was a certain sentiment against horizontal cooperation in the company leadership, there was accordingly no need for cooperative functionality. However, from another view there arose many ad hoc-situations that might call for flexible workers that supported each other. For example, when plumbers arrive to a working site, there is often more to be done than displayed on the initial order, and they may spend all day at the place. Then colleagues must take the other jobs that were assigned to this worker that day. Because these ad hoc-situations occur, assignments are often switched between workers by the foremen, and workers must drop in at the office between each job in order to receive a new one. No one were allowed to conduct ad hoc-assignments without the permission of the office. This was expressed by Tom in the following statement: "The plumbers' self-regulation equals zero, everything must pass through the administration. The office decides everything they do."

In the observation part of the case, the plumber "Stephen" was asked what he would do if something had come up and made this assignment difficult to carry out? He answered that he would call the office and ask one of the foremen of what to do. If there was a missing part, they would transport it to him, or if he was near the office/storage he would do it himself. He would not call one of his colleagues, but call one of the foremen first, in order for them to tell him who to call, and eventually come to his assistance. But this communication had to pass through the central, that is the office. While the company leadership downgraded the need for help-giving measures in the company, Stephen was very positive to the prospect of sending pictures wirelessly in order to receive problem-solving help, instead of going back to the office to show someone the picture he would take with a digital camera. It is interesting to notice, that they used pictures for description purposes in such communication. It was not always sufficient for them to describe the problem over the phone, something that not supports the conclusion of Kraut et al. (1996), who claim that differences in ICT does not influence success in collaboration. Workers claimed that pictures supported cooperation and problem solving better than conversations only.

Hierarchically constructed work practices, as found in the plumbing company, were also present in the electro companies. However, the management had a much more flexible relationship to their employees, and the coordination was less centered to the head office. For example, in Electro Company A, they carried out assignments for longer time-spans, and on these assignments, workers were often organized by a foreman on the working site. Cooperation is than based on face-to-face communication, and work is organized more project-based.

Among the blue-collar companies, the communication and cooperation seem to be on a vertical level, and this supports the strategy of the software company to develop a vertical solution. Workers are to a large extent independent in carrying out their assignments, and jobs are assigned to employees based on their skills and previous experience. This independence does not incite cooperative work, even though workers regularly need assistance. Only seldom would workers contact others to offer any help if they had some spare time. Then they would contact the office instead. This may be the result of the nature of their work, but also a result of the imposed work practice by the head office.

The use of the Data Collector supported mainly vertical cooperation, in the sense that more secondary work tasks were moved from the office to the blue-collars. The administrative staff in the plumbing company could tell that their work routines were changed after the implementation of Data Collector. Earlier, they had to electronically register all the information that the blue-collars had written on paper. Today, the work consisted of more control routines for checking the information that workers had already registered electronically.

The needs for cooperative support may be a function of the size of the company as well, at least when coordination of workers is the question. Considering a company with more than 100 employees, cooperative and coordinative support may be very cost-effective. MD outlines this scenario:

> "Consider a professional company with 120 employees, and you have 3 persons who receive new jobs. There is one order dispatcher and dispatching jobs is half-automated in the sense that you know the position of the employee. You know the competence needed for the job, you have a competence profile for the assignment, you match the profile with a list of potential employees who can install e.g. a fire-alarm. In addition, you know the location of employees so you know who are nearest the assignment location, you know who are leaders and who are on vacation. If you narrow down the potential employees like this, the dispatcher can tell that Anne and Knut can do that job. Large companies that run their business like this, they would have great benefits" (MD, my translation).

Even though the Electro Company A is a larger company than the plumbing company, the extent of cooperation and horizontal communication supported by ICT was not much larger. The reason for this was, according to the manager, that electricians often work together on a limited geographical area, and therefore communicate face-to-face.

The construction company

Another kind of blue-collar environment is the construction site. A construction site project involves normally a large number of different blue-collar professions simultaneously, and there must be a high degree of communication and cooperation between these. The construction site manager (CSM) explained that a lot of effort is put into working plans, and these must be followed. Most often, the work of one person or group of workers is dependent of others finishing their job. For example, masons cannot concrete a floor before plumbers have installed the pipes.

On the construction site, radios are often used as a synchronous, horizontal communication and cooperation tool, for example between crane operators and workers on the ground, where the communication must be synchronous. According to CSM, the need of asynchronous cooperation tools was much smaller. Blue-collars normally cooperate on primary work tasks and communicate face-to-face. A construction project engages both internal and external blue-collars. Internals are employed in the construction company. Externals are hired employees from blue-collar companies. The coordination of externals are part of the working plans elaborated days before they show up.

The vertical cooperation did not, according to CSM, require any mobile ICT solution either. He had regular meetings with the project manager, and regular face-to-face meetings with the foremen that organize work at different spots on the construction site.

Compared to assignment-based work practices, the blue-collars on a construction site project perform far less secondary work tasks than the ones in blue-collar companies. Thus, ICT-solutions for dealing with such secondary work were not required for these workers.

The brewery

There are some parallels between blue-collars and customer consultants in the brewery. They work on different locations away from the main office, and their tasks can be divided into primary and secondary work. The primary work of customer consultants is not, however, purposeful to compare to blue-collars. Customer consultants unpack bottles and cans of soft drinks after the drivers have transported it to the grocery stores. Ideally, the consultants therefore follow the route of the drivers, which requires coordination. The secondary work of customer consultants consists mainly of traveling (Kristoffersen and Ljungberg 2000) to the grocery stores. In some stores, the consultants are also responsible for ordering new supplies of soft drinks, depending on time of season and previous sales. These orders are transmitted to the logistics department of the brewery via the store's fax machine.

The brewery company provided the best examples of both horizontal and vertical communication. Customer consultants, also referred to as salesmen, are dependent of the delivery of goods from drivers in order to do their job. Any delays can be reported by drivers directly to the affected customer consultant, either asynchronously by messaging or synchronously by mobile phone. The company applies a priopt system, and every evening an SMS is sent to each customer consultant from the sales-planner. As the sales manager explained:

> "We send an SMS that informs that 7am the driver is at Stovner, you will spend 23 minutes on the job, 8.15am the driver is at Kampen. There is 200 cases of soda, thus you have 60 minutes. Then the guys know that the goods are there and there, you will have several meeting points and a decrease in

> wasted time" (Sales Manager, my translation).

The priopt system is based on a large amount of data, containing very detailed information about work practices and every grocery store. For example, the unpacking of a case of soft drinks is estimated to x minutes. The estimated time in each store is based on factors such as use of elevators, and how far it is between the storage and the point of exposition. Based on these data and the information from the logistics department, the working day of each customer consultant is planned in detail.

The system was implemented in 2002 in order to reduce overtime and even out the distribution of work between customer consultants. The different attitudes toward their own work made the old system unfair. Hard-working salesmen were "rewarded" with extra work, while more lazy employees worked much less for the same wage. However, according to the sales manager, both quick and slow employees complained about the new system. The quick salesman, who earlier was finished at 10am or 11am and then returned home, now has to work until everybody is finished. The slow salesman complains about the new demands of efficiency in his work. By becoming part of a team, they are put under pressure to work harder.

> "It is a win-win situation for the brewery [...] The customer consultants are discontent with the priopt...they feel it is wrong, the wrong time, everything is wrong in the beginning. But things work out better now, when people realize that changes come" (Sales Manager, my translation).

Customer consultant A reported that the cooperation with drivers worked well, and that drivers normally sends a message if they are delayed. He has a good relationship to the drivers and considers himself lucky that he only has to relate to three of them. That eases cooperation, because they get to know each other and routines are established, often regardless of the priopt system. Normally, he would only take a glimpse on the message he received from the sales planner, in order to see whether there were any new stores on his route. In this sense, the priopt system seems more valuable for temps, because they do not have established routes and work practices. Customer consultant A could not point at specific changes in his work routines after the introduction of the priopt system. He had always offered help to co-workers that were loaded with work. "It is stupid to go home when you know somebody still has to be working for hours" (Customer consultant A, my translation).

Customer Consultant B thought the work practices made him a "hermit". Mostly, he works alone, and makes little contact with colleagues.

He rarely asks other customer consultants for help, only if he has pressing appointments after work. In his view the consultants work in the same manner as before the introduction of the priopt system. He also claims that drivers do not follow the routes described in the priopt messages, but the route they think is fastest. Customer consultants must remember the standard routes of their drivers.

5.2.2 Mobility in case study companies

The mobility in blue-collar environments are primarily geographical, and closely related to the work practices in the companies. Historically, both blue-collars and salesmen have "always" been mobile. Today's work practices are strongly influenced by this background, and it is influenced of a world without mobile ICT and communication tools. For example, the use of papers as a communication tool is described in the previous section. In studying mobility, it has been important to understand the work practices and flow of information in the case companies.

The plumbing and electro companies

There was a distinct pattern of movement among blue-collars that worked on service assignments. The job is registered in the office and the employee often has to physically show up there to receive a paper document, or synchronize his PDA if the company uses Data Collector. In some cases, for example the Electro Company A, jobs are assigned to workers outside the office, but this is not a general picture. After receiving the order, the employee continues to the storage or wholesaler in order to gather the required materials for the job. Then he drives to the address where the job is done. According to the model of Kristoffersen and Ljungberg (2000), the modality of this mobility would be mainly traveling. Some wandering may take place at the working site. The participants of the study are all working on different locations. Workers doing short service assignments would go to 4-8 locations during a working day, traveling by their service cars. Others, working on longterm assignments, would be in a wandering mode, moving around in a building or a construction site.

Trying to generalize work practices in the plumber and electro companies, the normal flow of work and information proceeds as follows:

1. Reception: New orders are received in one of two ways:
    - The customer phones the company.
    - The customer contacts a worker directly, and the latter calls the office and informs about the new order. The registration

of orders are managed centrally, because only administrative staff are let into the ERP system.

2. Registration: The order is registered in the ERP system. Most customers are already registered, and in that case, only the customer number is typed. For example, in Electro Company A, a unique 5-digit order number is generated by the system, and the order is assigned to one or more employees by entering their unique employee number. By submitting the information, it is transferred from the ERP system to the administrative system of Data Collector. The order, with an order number and necessary information, is assigned to an employee. The assigned employee(s) will receive the order next time they synchronize their PDAs.

3. Synchronizing: The employee synchronizes his PDA. In the plumbing company and Electro Company B this was done by docking the PDA, in Electro Company A, it was done wirelessly via GPRS.

4. Materials: After receiving an order, the worker picks up the needed materials at the wholesaler's or in the storage. These are registered on the order number. The practices of picking up materials are different in the company. In the plumbing company they manage the storage themselves, and it is located to the same building as the office. Items are registered by either scanning the bar code or type it manually on the PDA. The Electro Company A uses a wholesaler located in the building next to their office, so the distance for picking up items is short. They also receive an eInvoice from the wholesaler within two days, which updates the order information in the ERP system. If it is a long-term assignment, e.g. during several months, materials are picked up in the same manner repeatedly. The Electro Company B uses three different wholesalers at three different locations, so they have the biggest job in collecting materials.

5. Performing the job: The timespan for completion of jobs ranges from a couple of hours to months. Between service jobs, workers often drive by the office to pick up new assignments. If workers are assigned to longterm assignments, they normally travel directly to the working site each day.

6. Hours and kilometers: Whether the assignment is completed or not, hours and kilometers are registered on the PDA every day.

7. Completion of job: After the job is done, the worker registers all the materials he has used, the time he has spent and he receives a signature from the customer. The accordance statement is filled

in. This is a checklist where the electrician grants that the job is completed in accordance with government rules and regulations.

8. Next time the worker synchronizes his PDA, completed assignments are transferred to the central system and the ERP system.

9. Invoicing: Based on the registered information about hours and materials the invoice is made and sent to the customer.In the plumber company the administrative staff would check the incoming information from plumber. Often the prices on materials were unclear, and then plumbers would set the price of an item to NOK 1,-. Then the secretary would have to calculate the right price. When the eInvoice from wholesaler is received, all necessary information is at hand, and the invoice is directly created by the economy department based on the registered hours and materials.

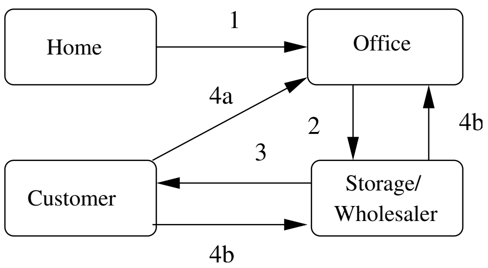

Figure 5.1: Pattern of movements

Figure 5.1 displays what can be called a worst case scenario in terms of maximum traveling length for workers. The plumbing company had the most rigid work routines when it came to patterns of movement. Everybody showed up in the morning at the office (1), for each assignment the car must be loaded from the storage (2) and after the job (3) is finished, unused materials must be unloaded back in the storage (4b). Then the plumber had to visit the office to receive a new assignment. Alternatively (4a), if there was not anything to unload after the job, they could go to the office directly.

Using Kristoffersen and Ljungberg's (2000) model of mobile IT use, the physical surroundings are at first the most interesting to study. However, it is also possible to argue that the physical surroundings of blue-collars have a distinct impact on the social surroundings. The fact that blue-collars have an individualistic attitude toward their own job, can be founded by the fact that they are spread across a large geographical area. This, in turn, may be a threshold for increasing cooperation.

Blue-collars in all the companies are mobile in the sense that their primary work tasks are outside the office. Geographically, their job sites are normally within city borders, and never more than a few hours by car away. Their patterns of movement are confined between the office, the assignment sites and the wholesaler. The only degree of variability is present for those who work on longterm assignments. They will not have to show up at the office daily. In Electro Company B there where some workers who operated on a nationwide basis.

Due to the differing time spans of assignments, employees do not necessarily visit the office daily. In longterm assignments workers show up at the assignment site. New jobs are assigned to employees both in the field and in the office. Mondays, employees will have to deliver their hour and material lists in the office. Since everybody shows up in the office at Mondays, meetings are also arranged at these days. The company does not have its own storage, electricians picks up materials at the wholesale merchants.

On a normal day, everybody shows up in the office, usually half an hour early for coffee and a chat. They pick up the already synchronized Pocket-PCs from the sync-stations. None of the plumbers know their assignments one day in advance. The foremen registers this the afternoon before or in the morning.

The construction company

On a construction site, movement was described much in the same way as Luff and Heath (1998) describe remote mobility. The construction site manager is responsible for carrying the project into effect. He also organizes the foremen, who are responsible for a various number of blue-collar workers on their respective parts of the project. These workers can be both internals, employed in the company, or externals, hired for a limited period of time.

The mobility of blue-collar workers on a construction site is normally limited to the site of the project, and to a specific task. Foremen move around more, while the construction site manager spends a lot of time in the site hut. Examples of the primary tasks of the CSM are making and adjusting plans, controlling hour lists and invoices from external work force, taking care of the HMS-regulations (Health, Environment, Security), and documenting work. Documentation is also an important task for foremen. Everything has to be done according to laws and regulations, and even blue-collars have to fill in check-lists to control their own work.

The brewery

The sales manager is not directly involved in the practical distribution of goods. He is responsible for the sales management in one geographical district, and is head of 40 employees.

The sales planner is responsible for distributing work evenly between consultants, and taking care of ad hoc situations when for example consultants have called in sick. Trained substitutes are recruited from a bureau, and may step in on short notice.

Customer consultants are responsible of unpacking and arranging goods in the stores. The distribution of products is organized in this way:

1. The transport planner produces driving routes based on the incoming orders from stores, and distributes the plans to drivers and the sales planner.
2. The sale planner produces the next day's schedules for each customer consultant and transmits these via SMS to the consultants.
3. Goods are packed at night and distributed to stores by the drivers from early morning.
4. Customer consultants follow the trail of the drivers, and unpack and arrange the goods in the stores. In some stores they also produce new orders based on the existing stocks, and faxes these to the company.

The cooperation between drivers and customer consultants are described earlier in this chapter. The modality of mobility among these consultants is almost exclusively traveling (Kristoffersen and Ljungberg 2000), and very equal to the assignment-based blue-collar workers. They spend a relatively short time at each location before they move on to the next assignment/grocery store.

5.2.3 ICT in case study companies

"Mobile computing consistently fails to live up to expectations" (Kristoffersen and Ljungberg 2000, p. 152). An important part of the case studies was to elicit what workers in blue-collar companies expect from ICT-solutions. Kristoffersen and Ljungberg have a rather pessimistic view, because they claim that users of mobile IT "expect, and, thus "need" the performance offered by stationary computing" (*ibid.*). Therefore, mobile computing will always seem like a disappointment because the result never exceeds the expectations. In the work environments of blue-collars and salesmen, this was not the case. Nobody expressed any need for such high performance. Some were glad they did not have to deal with laptops because these were too large and complicated to handle. The construction site manager did not see the need of laptops at all for his workers, neither did the sales manager in the brewery company. "PC-based systems for the blue-collar is out of the question" (Construction site manager).

At the same time, it is not said that they missed *better* performance of their ICT devices, especially the Pocket-PCs and PDAs they applied. There are still some basic problems with this technology, for example, limited battery capacity, OS crashes and screens invisible in sunlight. The following sections presents the use of ICT in the different case studies.

The plumbing and electro companies

The three studied blue-collar companies had all implemented the Data Collector. Before the introduction of the solution, a lot of administrative work was allocated to registration of order forms and material lists on paper that mobile workers had filled in. This means that most information is processed twice. Gathering all the required information related to an assignment becomes a bottleneck in the processing of the registered information of blue-collars into invoices that customers pay. This bottleneck means loss of income for companies. For example, if invoices of 1000 assignments are delayed an average of 7 days, this alone means 7000 days of lost interest of the incoming money.

Instead of this double registration, one solution is to let blue-collars register all information electronically on a PDA themselves. The central system of the Data Collector is located to the office, with a desktop interface for registration of in-coming orders. Customer's name, address, and job descriptions are registered, and jobs are assigned to employees. Workers "in the field" carry PDAs, which are synchronized with the central system regularly. They receive new orders, and information about completed jobs are transferred to the central system. Normally, this is connected with the ERP system of the company, which makes it fast and easy to make invoices. When it comes to mobile work, the product is designed to support the mobility of blue-collar workers. It runs on portable, handheld devices, and it allows synchronization via GPRS or GMS. The managing director expressed that the primary challenges of developing a mobile solution has not been understanding the mobility

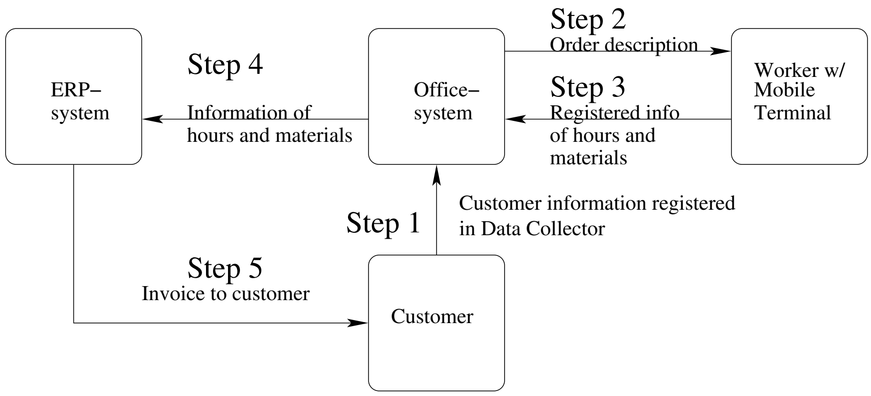

Figure 5.2: The flow of information.

of workers. It is fairly simple to map the patterns of movement of blue-collars. The goal of Data Collector is not to facilitate mobility either, but facilitate administrative tasks. Effectuation of the bureaucracy in blue-collar companies will probably have the the greatest economical effect.

The companies' point-of-view

For companies, the argument for implementing Data Collector in their enterprise, is fairly simple. It basically comes down to the case of economical benefits. "Return of investment (ROI) has become an important figure for determining whether to implement a mobile solution" (Mallick 2003, p. 3). This is partly the case of implementing the Data Collector as well. In addition, there is sometimes a "James Bond-factor [...] because they install electronic devices they are very absorbed in gadgets"(MD, my translation). The size of the company also plays an important role in the implementation of Data Collector:

> "The smaller the companies are, the more important becomes the emancipation of time...because normally you have a boss or somebody that spends the evenings or weekends to produce invoices and organize papers, and to reduce this is a point in itself, both related to family life but also to earn more in less time" (MD, my translation).

The managing director of Electro Company B has followed the development of the software solution for several years, but they have waited for the product to mature. He has not been interested in investing money in a computer system with too many flaws. The company has purchased 13 licenses, and managing director was alone in the decision of obtaining the system.

While Electro Company B has had a wait-and-see attitude, the plumbing company was one of the first users of Data Collector. This is due to the spark of interest from Tom, the owner and worker in the company. He is personally very technical interested, and could verify the MD's statement of users absorbed in gadgets. He alone took the decision to implement the system. However, the company still uses an older version of the system, because they are happy with the way things work, and will not be exposed to earlier problems of new version bugs, and tailoring of new systems.

To a large extent, companies and workers have expressed reluctance in making big changes in routines and work practices. The use of Data Collector has in many ways become a substitute for paper, and has had little implication for modes of mobility and the environment. The greatest changes are located to the office, and mostly affect stationary work routines, such as transferring data from paper to computers and making invoices.

Workers' point-of-view

While company administrators and managers could tell about some doubt among their workers before adopting the system, the interviewed plumbers and electricians seemed at ease with both the implementation process and the current situation. However, they are the ones who first meet technological problems as earlier described, for example when PDAs run out of power.

They did not have any strong opinions pro or con the Data Collector. Even though they were imposed by the management to use it in a specific manner, for example register information at once, they often did things their own way. This is possible since the management has very little control of what the blue-collars exactly do on assignments. As long as the primary work tasks are performed correctly, which is easily controlled with the absence of any customer complaints, the management often has to settle with that. This makes mobile workers to a large extent independent in performing secondary work tasks.

The construction company

Today, practically every worker on the construction site own a mobile phone. However, the phones are not provided by the company and it does not demand that workers possess one either. Construction site managers and gang leaders have been offered PDAs provided by the company, but it is voluntary if they want to use it. CSM could not see any instant needs of ICT on the construction site, especially when it comes to automation of communication. The most important flow of information between workers happens face-to-face or via radios.

For his own part, he could need ICT for overview purposes, for example, in keeping track of material orders. CSM is often responsible for ordering materials and that they are received at time. If workers could report incomings of materials when these arrive, it would be easier to keep track of these. Being an engineer, CSM could outline some specific advices for design and development of services:

- **Simplicity**: A system must require little maintenance from the company, and the service must be tailored to specific needs. An extensive software package is not attractive for a company. PC-based systems for blue-collars are out of the question. PDA-based systems are easier, while everybody knows how to handle a mobile phone.

- **Documentation**: The possibility of work documentation is crucial. This was a point he made several times during the interview.

- **Implementation**: Start with small services or systems, and try them at workers that are genuinely interested.

- **Interface**: Blue-collars do not like to write, services should not require much punching.

Only the last issue concerning interface design deals particularly with individual design requirements. This can be interpreted in favor of the importance of contextual, organizational design requirements.

The brewery company

The use of ICT beyond mobile phones was not extensive among customer consultants in the brewery company. However, the company had an ongoing strategy of equipping every mobile worker in their company with PDAs, and connect them to a new priopt system, still under development. This would be a ICT coordination tool for the company, which also included the possibility for salesmen to e.g. register orders in the visited grocery stores. Today, such orders are faxed to the central office, which sometimes implicate problems when they have problems connecting with the fax machine due to various reasons, most often fax machine jamming at the office.

5.3 An Activity Theory analysis

As mentioned in the introduction of this chapter, Activity Theory is an analytical tool for discussing and analyzing the gathered empirical material. The theory serves as a bridge for bringing empirical findings into design requirements. The justification for using AT is discussed in chapter two. The work of blue-collars and customer consultants can be divided into primary and secondary tasks. While ICT has very little consequences for the primary work tasks, most focus will be on the secondary tasks as collective and individual activities.

Regarding blue-collars and salesmen, all assignments and visits of stores may be treated as *collective activities* (Bødker 1991), the sum of *individual activities* and chains of actions such as registrations of jobs in the ERP or priopt system, performing the primary work, registration of information and process invoices. Normally, this require the cooperation of at least two or three persons, one in the office and one blue-collar or salesman. The goal or object of this collective activity may well be seen as finishing the workload of the whole organization in one working day. This kind of collective activities are examples of *vertical* cooperation, which is found in every case study.

However, believing that everybody perceives their work as a collective activity would be naive. Trying to change the attitude of workers toward a notion of "joint work" can be done by introducing team-based work organization, such as the case of the brewery. Sharing primary work tasks is also a way of turning activities into collective efforts. On large-scale assignments, several blue-collars are often assigned to these, and work is distributed on the working site. In this respect, blue-collars and administrative employees may share a common object.

Blue-collars on service jobs and customer consultants often perceive their work as individual activities. They have a strong notion of their primary work as important, while secondary work is necessary trouble. Workers often perceive the completion of their primary work task as their goal of their activity. It is hard to see why else workers normally register hours and materials many hours, or even days, after they have completed the task at the customer. Since workers both in the blue-collar and brewery companies identify with their primary work, they have developed a very individualistic perspective on their work situation. Customer consultant B in even regarded himself a hermit in his job. The reasons for this may be the geographical mobility of workers, and the rare occurrences of shared primary work tasks. This mismatch of collective and individual objects or goals of activities will probably be a potential conflict or breakdown in the case of enhanced horizontal cooperation related to secondary work. Blue-collars are used to focus on their own assignments, and not bother with what others do in theirs. When they have to shift their focus toward collective objects, their work practices will have to be re-conceptualized (Bardram 1998).

Breakdowns will often occur when assignments and jobs are altered in size and usage of time. This should call for an increased level of cooperation and coordination. However, in the plumber company this is solved by increasing the level of mobility, or rather movement. This is an example of how *mobility* is used to avoid breakdowns. Instead of offering flexibility to workers, the work practices force them to visit the office and storage between each assignment. Having flexible work routines could imply that workers were allowed to judge their own need of mobility. For example, if a plumber has two assignments in the same neighborhood, it would probably cut costs to load the car for two jobs and drive the route of office(A)-assignment (B)-assignment (C)-office(A) instead of A-B-A-C-A.

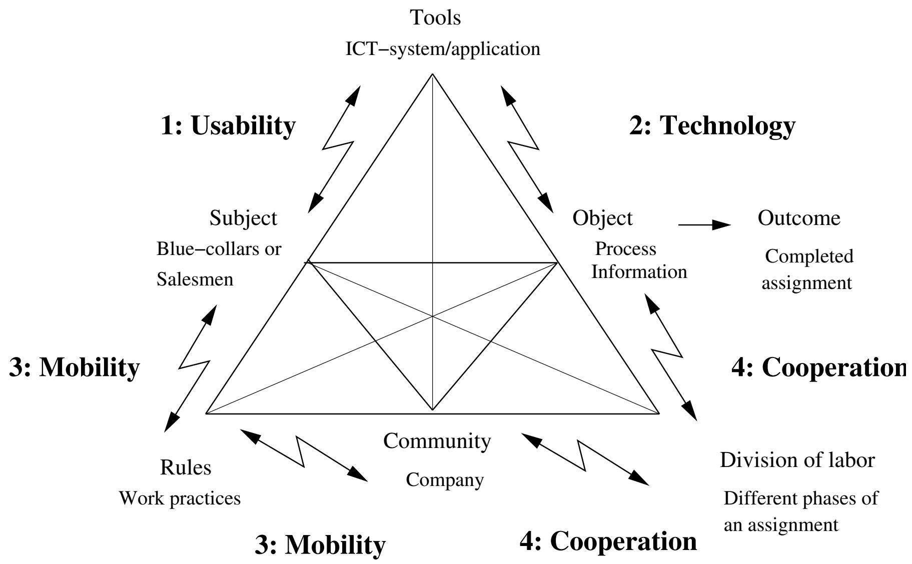

Figure 5.3: Potential breakdowns in the activity system

Figure 5.3 is an extension of the model of Engeström, and inspired by an article where Engeström and Masu identify breakdowns between designers and users in an activity system (Hasu and Engeström 2000). This analysis will concentrate only on the company cases as activity systems in an attempt to elicit potential breakdowns for designers to be aware of. There are especially four conditions where breakdowns may occur. In this particular activity system, the collective activity is all secondary work attached to an assignment. The object of the activity is processing all the needed information.

1. Usability

The use of an ICT system is a certain source for breakdowns. The interaction between the user and the system is always a challenge, thus usability requirements are always important for the success of a system that interacts directly with humans. In the study of the Data Collector, it is evident how crucial usability questions are;

> "I have made more than a hundred visits at customers during one and a half year, so I have talked with many who have had dirtier and much bigger hands than me, and they explain things that makes it evident that you cannot think all IT-technology and what is fancy, Java etc. If you say to an electrician that 'you shall use [Data Collector] and you must connect it via GPRS before you can use it', then forget it...it will disappear into the drawer within a micro-second" (MD, my translation).

The specific requirements, elicited from the case studies and related to usability issues, will be further elaborated in the next chapter.

2. Technology

Technology is also related to usability issues. Technological constraints and possibilities influence the degree of usability of a device. For example, a mobile phone is for many easy to handle, and you may connect directly to a server with only a few keystrokes. For others, keys on the mobile phones are far too small for their fingers, and blue-collars are known for their big hands, which makes mobile phones troublesome.

In the empirical material of this thesis, there are also examples of technological challenges which may create breakdowns, and loss of information. For example, workers have experienced that their PDAs has crashed, and all the information about their assignment has been lost. These are serious incidents, that may lead to economic loss of the companies.

3. Mobility

The mobility of workers in the studied companies leads to a certain distrust toward blue-collars from managers. This supports Perin's (1991) discussions of social fields and invisible workers. This is shown, for example, in the plumbing company case by the fact that they tested whether workers really read the control lists. In addition, employees were also obliged to register information twice both on paper and in the Data Collector. This was partly due to the possible technological breakdown of Data Collector, but also because administrative staff would have the ability to control digitally recorded information against information recorded on paper. They claimed that there often was a mismatch between the recorded information, and the reason for this was that workers did not follow the *rules* of registering information carefully enough. The manager of Electro Company B also claimed that the main reason for implementing Data Collector was to reduce losses of materials, insinuating that employees do not follow the rules when registering the material. Blue-collars also reported that they did not always register information of assignments shortly after the completion of these. In worst case it could take many days, and registered information was often based on memory. Sometimes, for example in Electro Company A, they would register information in a note book and later register it in Data Collector.

As these examples show, employees do not follow rules as carefully as company managers wish. A good explanation for this, both deducted from theory and empirical material, is that workers are invisible for managers, and can organize many of their activities in their own manner. In addition, when their notion of own work as an individual activity is combined with mobility, this is a potential breakdown in cooperative work.

4. Cooperation

The studies of the Data Collector show that the implementation of this technology influences the *division of labor*, by the fact that more administrative tasks are transferred from office staff to blue-collars. Grudin (1994b) warns against workers who are introduced to increased amount of work without experiencing the benefits of it.

In designing a CSCW-solution for blue-collars, it may be valuable to consider the three levels of collaborative work (Bardram 1998), displayed in figure 2.1 at page 16. In the plumbing company, they were extremely concerned with keeping work on a co-ordination level, avoiding co-operation and especially co-construction. Work routines were fixed, and everybody knew what to do in an ad hoc-situation. Designing a solution for horizontal cooperative work in this company would seem superfluous.

5.4 Summary

Six companies are objects of the case studies in this thesis; one software company, three blue-collar companies, one construction company and one brewery. The primary goal of these case studies was to answer the first problem definition, and distinguish the important features of mobile cooperative work. Since this thesis also focus on the design of a CSCW-application, it has also been important to investigate the use of ICT in blue-collar work environments. *Cooperation* is found in all companies, but more vertical than horizontal cooperation is detected. One company even put restrictions on horizontal cooperation. The brewery had introduced a more team-based work organization and horizontal cooperation was more appreciated in this company than in blue-collar companies. *Mobility* is in general geographical. The modalities of mobility depend much on the organization of work, traveling is found much in assignment-based work practices, while wandering is found in project-based work practices. In studying *the use of ICT*, the Data Collector is focused on. The management of companies are generally positive to this solution because it has cut costs, and makes secondary work more effective. Workers do not report any strong sentiments in favor or against the solution. One reason for this may be that, as mobile workers, they control much of their own working habits, and becomes independent in many of their work routines. This was also a feature of the customer consultants in the brewery. This independence also creates individualistic workers, which this thesis proposes, is a threshold for creating more cooperative work practices. Mobility also results in a need of control for company managers, because workers operate in social fields. It is in some companies a direct mistrust of employees, but also inherited work practices from a time where it was not possible to communicate wirelessly. In this case, mobility restrain cooperation, and it continues to do so, because companies express a certain contentment in the things work today. An increased degree of cooperation implies a change in work routines, which many resent. The implementation of Data Collector shows this. The ICT system is often adopted without consideration of changes in work practices. It becomes a replacement, or sometimes only a supplement, to the use of paper. In the brewery case, we found a large company with focus on change in work practices. In this organization, cutting costs and increasing efficiency are primary goals, and this has resulted in the introduction of teamwork, instead of individual accord-based work.

The subjects of cooperation, mobility and use of ICT are joined in an activity system. By discovering present and potential conflicts and breakdowns in this system, it is possible to elicit design requirements based on these breakdown scenarios. In the analysis, four cornerstones of a CSCW-application is defined; usability, technology, mobility and cooperation. While usability and technology address requirements on a individual level, the mobility and cooperation address requirements on the contextual level. In the next chapter, specific requirements within all of these categories will be presented and discussed.

Chapter 6

Designing applications

In this chapter the focus will shift from the mobile cooperative work of blue-collars and salesmen to the work of designers. As concluded in the previous chapter, both individual and contextual aspects of mobile cooperative work must be evaluated in the process of designing CSCW-application. Therefore, this chapter deals with design on two levels; one level for the individual user, emphasizing usability aspects, and one contextual level, focusing on the features of cooperative work as joint efforts and chains of actions in an organization.

As described in the previous chapter, the first work hypothesis stating that there presumably would be a high degree of mobility and cooperation, has to a great extent been confirmed. Mobility was the easiest of the two to categorize and generalize. The cooperation in the different cases was harder to generalize, and in some cases, horizontal cooperation supported by ICT seemed absent. Especially regarding the plumbing company, it is hard to imagine that this company would even consider to implement an ICT-application supporting horizontal cooperation. However, one cannot derive from this that horizontal cooperation is absent in blue-collar environments in general. Therefore, the discussion of designing ICT for mobile cooperative work is primarily based on the brewery case, literature, and some of the prospects outlined by the managing director of the software company.

Figure 5.3 in the previous chapter, page 74, displayed some main areas of concern in the activity system of blue-collars and salesmen. In the further design and development of a mobile ICT system, these challenges should be taken into consideration. First, the usability aspect is very important. Second, technological challenges are also crucial to consider. These are important features of the application as a mediating tool between workers as subjects and the common goal of the activity. The issues are treated under the section of individual design requirements, because they are predominant in the relation between the individual worker and his ability to contribute to the collective activity. Third, many rules and work practices are historically developed by mobility, and the implementation of ICT may influence this mobility. Fourth and last, the implementation of ICT, supporting cooperation, influences the work practices and may alter the division of labor. This is not necessarily a painless process. These issues are treated under the section of contextual design requirements, because they relate to the organization as a whole.

6.1 Individual design requirements

Initially, the development of the Data Collector was based on an extensive amount of studies and interviews with blue-collar workers. "When you make systems that have a relation to users, and most systems have that, you won't sit for long behind your desktop before you fail" (MD, my translation). In order to succeed it is vital to do your homework, and the reasons for failures are often systems that are driven by technological opportunities instead of users' requirements. However, a challenging part of that work is eliciting those requirements. "When you ask a user, he doesn't realize his own well-being, so you will only receive a maximum of 20-30% of the requirements from a user. The rest is your job as a bridge between system and user to elicit" (MD, my translation).

6.1.1 Usability

Usability is a general concept, and can be defined as a "system's adaptability to the organizational, work-related, and technical contexts" (Mathiassen, Munk-Madsen, Nielsen, and Stage 2000, p. 178). Thus, usability concerns issues of interface design, technical possibilities and existing work practices. In this thesis, however, usability is mainly used in describing the interaction between the user and the machine/device.

On the individual level concerning usability, a lot can be learned from the managing director of the software company that has succeeded in designing and developing a solution. He emphasizes strongly the usability requirements in a solution. Naturally, this is a result of his position of developing a product that must sell, but everybody should be interested in developing something useful.

> "Daedalus Research Group [...] made a very fine research report which among other things said that don't try to change

> skilled employees, who work in this manner, to become office staff. Thus, if you show up with such a tool [a laptop] with lots of opportunities, a portal solution and everything possible then forget it...Define the core functions, the core tasks and tell them this is what you want to solve" (MD, my translation)

In the next chapter, a scenario will be outlined in order to define the "core functions" in a future CSCW-application. In marketing the Data Collector, MD also introduced a term called the 10-seconds rule.

> "I found a name for it, because so many [workers] always told me that: 'No, this is too troublesome', 'no, it takes too much time', 'it has to go fast'. And that alone is a reason for saying that thin clients today are not usable to that kind of registration" (MD, my translation).

The 10-seconds rule implies that during this period a user shall be able to pick up the PDA, turn it on, edit or register information, turn it off and put it back in his pocket. Thus, time is an important usability requirement to consider.

Workers also confirm this view, as many of them underline the stress and lack of time that follows their work. However, this was seldom the case when we observed their work. Tom in the plumbing company also moderated the importance of the 10-seconds rule, by saying that "10 seconds isn't that important, we would have used the Data Collector even though it was slower, say 30 seconds or even up to a minute. It is hard tell exactly" (my translation).

Still, in designing services for these users it is very important to consider the notions that blue-collars have about their own situation. All of the workers we spoke to could, in a designer's view, easily spare five minutes of their time to register information. But the workers' experience of a stressing job would often make them postpone the registrations until after working hours, even though they were required to register information immediately. Instead of registering information regularly into the Data Collector, many preferred to make notes on pieces of papers or in notebooks until the assignment was completed. Then they would register everything at once into the Data Collector. Thus, the usability of paper and pencil seems to surpass the usability that a computer system may offer, because it is more convenient and faster to write something on a piece of paper.

In a system that supports cooperation, use will normally be allocated to working hours, thus an important usability aspect is that the application connects to and communicates quickly with the server. Speaking in favor of such a system compared to the Data Collector, it will not be a substitution for previous paper systems, so workers can not choose whether to write something on the PDA or a piece of paper. Therefore, a one-to-one comparison between the Data Collector and a system designed for cooperation purposes in particular is not purposeful, but some features are similar.

Another important challenge is how to design application details. Often, needs and requirements are hard or impossible to predict, and therefore the software must be easy to alter and upgrade. It also becomes a question whether the needs of one user is applicable to all users. This becomes extra challenging in the development of a CSCW-application where so many opinions should be taken into consideration (Grudin 1994b). MD could tell that their customer service receives a lot of feedback from users, and these often regard very specific needs such as:

- Attaching more than one end-control list to an order.
- Being able to make order descriptions longer than 25 lines.
- The accordance statement must be able to refer to more precepts.

These are examples of functionalities that people unknown to the daily work of blue-collars will have great problems to define in advance. Designers may follow a plumber for a week without such challenges coming up, and workers will not think of such problems until the moment they occur. The challenges in designing systems for blue-collar workers will be influenced by the problems of generalizing the mobile cooperative work. Looking at a limited number of cases in this thesis, there are fairly big differences in how ICT technology is regarded. In designing CSCW-application one should therefore expect a highly dynamic process where new needs and requirements appear after implementing the system. Making generic solutions that are relatively easy to tailor depending on each companies' size and needs is a good strategy, such as the software company has done.

In the beginning, Data Collector addressed electricians, and later it has been introduced to new groups of blue-collar workers with many of the same needs, but also with deviating requirements. This has resulted in the possibility of tailoring the product for one owns needs. The later development of the product has also been done after close contact with users, listening to their needs and complaints, and considering what is possible to generalize and implement, and what is too specific.

Data Collector is tailored to the work practices in the plumbing company, and Tom underlines the importance of this in a computer system. The fastness is important, even though the 10 seconds rule is a bit exaggerated according to Tom. For them, the possibility of connecting a bar-code scanner to the Handheld PC is one of the most important features. “Bar-code scanner is a must”, according to Tom.

In the other companies this possibility was not used. In Electro Company A, it was important to synchronize the PDA via GPRS, while the plumbing company only used docking stations in the office. The language should be the native language of the workers. As one electrician in Electro Company B expressed it, when problems with the PDA arose it was scary “to reset it [the machine] without knowing what is going on, it is not everybody who is familiar with reading English text messages or English error messages.” Responding to a follow-up question whether error messages should be in Norwegian, he said: “Yes, then you would have an opportunity to dare or not to dare [laughter]”. This is one of the reason why the prototype in this thesis is developed with an interface in Norwegian. Dealing with such a small system, conversion of interface languages will not pose any problems. However, none of the other participants we spoke to, said language was a problem. They were not asked either, so it is impossible to say if this is a general requirement or not.

The conclusion drawn from this discussion is that systems should not be too specific at once. With so many needs and perspectives, this alone is a great challenge for making CSCW-applications, just as Grudin claims (Grudin 1994b). The construction site manager, being an engineer himself, could outline some of the requirements he thought would be important in the design and the development process of ICT services for blue-collars both on construction sites and elsewhere. Simplicity is a key issue in this regard. First, a system must be simple and require small maintenance costs and efforts for the company. Services should address specific needs, and in that regard, extensive packages of software are not attractive. Second, blue-collars should use PDAs and mobile phones because of their portability, and services should not require extensive use of keypads, because “blue-collars don’t like to write” (CSM).

6.1.2 Technology

As pointed out in chapter three, the rapid development of mobile ICT devices offers continuously increased opportunities for users and designers of mobile computing. For example, more functionalities are added to mobile phones and the quality is improving. Still, for designers, technological issues pose challenges that must be considered, for example what happens to data when the device runs out of battery. In addition, the rapid development may also have some clearly negative side-effects. For example, less time and resources may be spent on device testing. A study by Intuwave[1], shows that device flaws and poor customer service threaten the adoption of smartphones and services. "Only 40% of IT managers had confidence in Smartphones"[2]. The report concludes that testing and customer service issues should clearly be addressed.

Several participants in the case studies reported about problems when their PDA crashed or ran out of power. Both the stored information about jobs and the configuration of their software was lost. The consequences were of varying severeness, depending on when the PDA was last synchronized, but everybody looked upon this as problematic. Historically, technological immaturity has also posed the toughest challenges for the software company and MD in developing a successful product.

> "It has been a long run for five years when it comes to maturing of terminals, of mobile networks, both hardware and software, not only our own, but also [...]'s and others' that are part of the solution, and it has been a hard run" (MD, my translation).

While MD referred to Data Collector as a rather "thick client", because it can carry a lot of information, it has all the features of a smart client presented in chapter three.

> "[Data Collector] is an intelligent data collector, which we can make much more intelligent now than earlier. First, because that type of technology is an adequate 32-bits platform, where you can make good stuff, and second, is has a fair amount of memory so you can bring much around. And an important issue in your thesis is: What about thin clients versus thick clients, and why should they be thick for another while, but successively with thin-clients' features" (MD, my translation).

The main problems have been the limited battery capacity, especially in cold weather, the sudden loss of data, limited bandwidth and generally poor performance. As one electrician in Elector Company B explained,

[1]http://www.intuwave.com. Accessed May 10th 2004.

[2]http://www.intuwave.com/index.php?page=news_articles&id=90. Accessed May 10th 2004.

he had to take good care of his PDA or it would easily break, and if he did not charge the batteries in time information could be lost. However, he did not take backup of data, because starting up and shutting down the machine took too long. An argument in favor of thin clients is the storage of data. In a thin client architecture, data is stored in the "central" system. That is, in case a worker's mobile phone is lost, stolen or the application crashes, the loss of information and data is limited to a minimum. On the other hand, a thin client architecture demands nearly 100 percent access to the server, which might be risky to be dependent on. As experienced in the brewery company case study, the operator network collapsed half an hour before our meeting/observation with one of the customer consultants. Luckily, everything was arranged the day before, because when we arrived at the grocery store, the consultant was not there. A delayed driver had made him visit another store first, but since we knew which stores he was going to visit that day, we could figure out where he actually was. A potentially troublesome situation, or breakdown, was avoided by the fact that the customer consultant knew the route of the driver, and could adjust his own route to this. Thus, cooperation can not be too dependent on use of ICT technology, there has to be some predictability in plans and routines.

No designer of any computer system has unlimited technological resources, and one has to deal with the technological constraints, especially in applications designed for mobile devices which have limited resources (as described in chapter three).

Limitations in bandwidth should result in a system with a smart client architecture, where the user will not have to connect to a server every time he has to register data, which are not important to share immediately. The user should also be able to decide which data that are transmitted at each upload or download. For example, in the Data Collector, *all* completed assignments were uploaded to the server when users synchronized their PDA, and these assignments were "frozen", that is impossible to edit. Workers in Electro Company A did not like this, because it happened occasionally that they discovered details that were forgotten when they registered the assignment information. If they had marked the assignment as completed in Data Collector, it was not possible to add extra information. It would be purposeful to be able to synchronize only one assignment, especially if the user is in a hurry, and does not want to wait for all assignments to be synchronized, which can take considerable time if it is done via GPRS. Thus, being able to adjust the information to be synchronized dependent on the situation should be a requirement.

The limited memory and power capacity in mobile devices is an argument for designing systems with a thin-client architecture. In a system that should support cooperative work, it is also questionable how much information is needed to be stored on the device, because information should be shared rather immediately. When there is little stored information on the device a technological breakdown (in the activity sense), will not be that severe in terms of lost information.

6.1.3 Summary of the individual design requirements

Figure 6.1 on page 87 is an overview of requirements on the individual level, and it also gives suggestions on how to solve the challenges and implement the requirements. Some of these requirements are examined in the prototype, page 98. The speed of the application, the development of the interface, and making a flexible solution are especially focused on in the prototyping.

6.2 Contextual design requirements

The next step is to look at the context, the work environment workers operate in. As pointed out by many researchers, e.g. Grudin (1994a), organizational design and change is an important issue in making CSCW-applications. What was learned in many of the blue-collar companies was that they were skeptical to make big changes in their work practices. This is discussed further in the next section.

One should be very careful not to judge todays work routines as undynamic and inefficient, because leaders oppose organizational changes. At the same time, if groupware should be implemented in the studied companies in a purposeful manner, it would require some changes. Workers would have to be more flexible, and adjust to the "new work life" (Eriksen 2003). In a large company such as the brewery company, making workers flexible was much more on the agenda for the management. Here, flexible workers were looked upon as valuable, while blue-collar companies did not emphasize this as important.

6.2.1 Mobility

Mobility is defined as one of the four factors that is important to understand in the design of a mobile CSCW-application. In chapter five, geographical mobility, the pattern of movements, was pinpointed as the interesting type of mobility to look at. It is important to understand how

Requirement	Solution/Implementation
Application speed. Consider the 10-second rule.	Efficient programming algorithms. Using threads for wireless connection and read/write to memory.
Application speed. Remote connection.	Make amount of data scalable. Make synchronizations "to the point" and tied to the functionality.
Interface simplicity. "Blue-collars don't like to write"	Limit the number of keystrokes. Drop-down boxes. Word-list (T9).
Flexibility. Make room for new information/functionalities that are hard to specify in advance.	System modularization and component-based design.
Safety. Device runs out of power.	Application on mobile clients must make regular backups.
Safety. Unable to access remote server	Application must have storage possibilities on mobile client. Smart-client architecture.
Security. Device is lost/stolen.	Access from the lost device should be easily denied from administrator.
Portability. System applications should be available for PCs, PDAs and mobile phones.	Design web interfaces for PC. The applications for mobile phones should be portable to PDAs or smartphones

Figure 6.1: Individual level requirements

these patterns of movement have developed, and which functions mobility play in the work practices. In these work environments, companies could save money for example by decreasing the number of kilometers driven and the time workers have to spend on the road.

As an example; if every worker in a company with 20 blue-collars saved half-an-hour every day during one year (approximately 200 working days) by less driving and every worker drove 20 km less every day. Let us also assume that the company earns NOK100,- for every half-hour the workers saves in, because they can spend their time on primary work tasks instead. Let us also assume that the company's expenses for every 10 km driven are NOK 7,-. Even with these modest estimates, it is possible to show that driving less and decreasing the traveling, could be cost effect-

```
Savings on hours:
20 (employees) x 1/2 (hour) x 200 (days) x 100 (NOK)
                                        = NOK 200 000,-
Savings on fuel:
20 (cars) x 200 (days) x 14 (NOK per 20 km)
                                        = NOK  56.000,-
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Figure 6.2: Calculation of economic savings

ive. However, there could be other than economic reasons for upholding a higher level of geographical mobility.

For example, in the plumbing company everybody showed up in the office every morning for a coffee and a chat. We would consider this as an important routine for maintaining social relations in a company where people are located at different sites during a working day. In addition, workers also showed up in the office for lunch breaks. From this perspective, the work environment in this company seemed very positive. However, this extra traveling to the office can from an efficiency perspective seem like a waste of kilometers driven and time spent on the road. Instead, they *could* do as Electro Company A, where employees often traveled from home directly to the working site.

There were also more reasons why plumbers in the plumbing company had to visit the office, normally between each assignment. One reason is earlier described as the management's desire for keeping control of where employees are. This is interpreted as a direct result of the fact that workers are mobile and “invisible” for the management for large parts of the working day. The need for control was also displayed in the work practice of loading and unloading the service car between each assignment. After receiving the order, the plumber visited the storage for loading the car with the required materials, and every items was registering to the order using a bar-code scanner. When the assignment was completed, the remaining items would have to be unloaded and subtracted from the order, using the same bar-code scanner, and marked in the Data Collector with a minus. As outsiders we thought this seemed inefficient, but the management responded to this with the need for the employees to keep control and overview of the contents of their cars. If things were otherwise, everything would turn into a mess.

In all of the other cases, work practices were not as rigid as in the plumbing company. In both the electro companies, workers did not have to visit the office so often, but in these companies, the amount of long-time assignments were bigger, and the organization of these were in a higher degree delegated to the foremen "in the field". Workers at long-time assignments in Electro Company A would visit the office as seldom as every fortnight. Thus, the work practices on these assignments were often more similar to project-based work practices as we saw in the construction site company. The modality of mobility in such project-based work practices is wandering (Kristoffersen and Ljungberg 2000), while the modality of mobility in assignment-based work practices is mostly traveling.

One of the main purposes of studying the use of Data Collector in blue-collar companies was to examine how a mobile ICT-system influence the work routines in an organization. In particular, looking for changes in work practices was an important issue, which is why one of the selected companies, the Electro Company B, was an organization that was in the process of implementing the Data Collector.

To a high degree, the Data Collector was a substitute for existing registration systems. The main reasons for implementing The Data Collector were never reported to be a more dynamic or flexible organization. For example, in Electro company B the main reason was to decrease the losses of materials. In Electro company A, one electrician reported that things worked out as earlier, that is before the implementation of Data Collector, apart from a smaller volume of papers.

For example, Tom accepted that work routines *may* be improved, but the company follows the philosophy of "we know what we have, but don't know what we get". As long as it works, everybody is happy. Thus, the prospects of a more *efficient* and *flexible* organization is not necessarily sufficient arguments for implementing an ICT solution in the company.

The cases indicate that even though companies implements mobile ICT in their organizations, this has had little influence on the mobility of workers. This thesis suggests that the reason for this phenomenon is the the close relationship between mobility and the existing work practices. Changing mobility, or rather the patterns of movements, would influence the work practices more than the management would appreciate. This can be see as a fear of breakdowns in the organization, in case new routines and rules should alter existing work practices too much. Therefore, designers of CSCW-application should consider the influence that their system has on mobility in the company. Too big changes will probably not be appreciated.

6.2.2 Cooperation

How employees cooperate, and how this is organized, is the fourth important factor important to understand in designing mobile CSCW-applications. For designers, it is also important to know what cooperation, or collective activities (Bødker 1991), that is possible and purposeful to support. The modality of mobility influences the way workers cooperate, and just as important not cooperate. This thesis suggests that work practices that are influenced by the *traveling*-modality of mobility (Kristoffersen and Ljungberg 2000) are the most purposeful to support. In assignment-based work practices, we found the least occurrences of cooperation, and this thesis suggests that here is also the biggest potential for applications that support cooperation. Earlier, cooperation related to these work practices were hard to support. Today, ICT *may* serve as a tool for enabling more cooperation if this is desired.

In project-based work practices, influenced by wandering mobility, cooperation is often supported by face-to-face communication. This was the case in Electro Company A on longterm assignments and in the construction site company. For example, the construction site manager could not come up with any ideas of how an ICT system could support the horizontal cooperation on a construction site. Luff and Heath (1998) claim that the failures of the mobile system for foremen on the construction site, were a result of developers not focusing on the right activities to support, or that the system did not address the activities in an appropriate fashion. This thesis suggests that work practices with a high degree of interpersonal communication should not be prioritized activities for ICT support.

Cooperation also means a division of labor, and how ICT influences this division is also an important issue to consider in the development of a CSCW-application. Even though the Data Collector today may not be considered a groupware, many of Grudin's (1994b) eight challenges for developers of groupware were found in the case studies of Data Collector and the companies. "Groupware applications often require additional work from individuals who do not perceive a direct benefit from the use of the application" (*ibid.*, p. 97). This was certainly the case in the use of Data Collector, since office work, which previously was assigned to administrative staff now is distributed to blue-collars. For workers who previously registered information on paper, the use of Data Collector often means additional time and effort in registering data. Thus, the division of labor has been changes in the division of labor, and potential conflicts in the case study companies were searched for. Only workers who originally had administrative work tasks see the benefit of this additional work. However, it was hard to find any strong sentiments against the additional work from blue-collars, but they did not joyfully embrace the new routines either. In the brewery, the sales manager reported very negative attitudes among employees toward the process of implementing ICT and more team-based work practices. However, the interview customer consultants did not regard that process as problematic.

Many of the problems Grudin (*ibid.*) presents are solved in a manner of force. Even though workers do not see the benefit of the Data Collector, they are obliged to use it. In this way the problem of a critical mass (Grudin's second challenge) is also solved. Demotivating factors among employees were not much considered in the studied companies. The social, political and motivational factors that Grudin treats are present for blue-collar companies. In the plumber company, they sometimes changed the description of checklist to contain tasks as "Been to the liquor store (Vinmonopolet)", in order to control whether the employee paid intention to the instructions. As earlier stated, the company's management wanted a high degree of control. Data Collector was occasionally used as a control mechanism. In this way, the technology does not become a threat to power structures from a manager perspective. In the adoption process of the Data Collector, managers reported that even though employees were allowed to express their opinions of implementing a new system, it was the managers alone who decided whether the company should buy the system. However, no managers nor blue-collars reported any great dissent between employees from the implementation process.

Many of Perin's (1991) points are applicable in this case. "Groupware confronts the conventional bureaucratic model for effective communication and coordination, which requires employees to be present and accounted for at the same time and in the same place" (p. 76). In the plumbing company, the manager relied on the "principle of employees' *visibility*" (p. 76, author's emphasis), in order to carry out actions of control and coordination. In the blue-collar companies, it is not groupware or cooperation that challenges the principle of visibility, it is the mobile feature of their work, pointed out in the previous section. "Managers can distrust and delegitimize even those who have already proven to be high performers if they work out of their sight" (p. 78).

6.2.3 Summary of the contextual design requirements

Figure 6.3 on page 93 is a summary of the contextual requirements that can be met in the design and implementation of the system. These are based both on the aspects discussed this section, and some of the discussion regarding individual design requirements as well. Just as important are the considerations that must be taken in the organizations that implements such a system. For example, this thesis suggests that Data Collector would have been a bigger success in the studied companies, if they were willing to adjust to more efficient work practices. But to suggest for companies how to change work practices would maybe be regarded as an intrusive act. The software company's managing director was also focused on usability and technological issues regarding the Data Collector, without addressing much of the contextual problems we found in the companies. Designers should also be able to propose how contextual challenges *could* be solved. For example;

- Introduce incentives (economic?) for using the system correctly. This can prevent mobile workers from doing secondary work their own way. If the company saves money as a result of implementing an ICT solution, workers should be rewarded. (This was also done in a company that used Data Collector (not a case study company), that had a decrease in material losses after the implementation of the Data Collector.

- Introduce more team-based work practices if work is to be performed more flexible and with a higher degree of horizontal cooperation.

- Be aware of changes in the division of labor. If stakeholders do not see their benefits of added work, or troublesome changes in work practices, measures for crediting workers for extra work burdens could be introduced. Introducing team-work may also make a shift in attitude from "my" work to "our" work. This shift in attitude from individual to collective activities could have an positive impact on horizontal cooperation.

6.3 Summary

Design requirements of CSCW-applications can be categorized in four groups at two levels. The individual design requirements are important in order for each member of a group to participate in a collective activity supported by ICT. CSCW-applications are particularly vulnerable for not reaching the desired critical mass of users, since users that do not participate in the collective activity may break the chains of actions that cooperation consists of. Therefore, the individual design requirements address the challenges of the application as a mediating tool between

Requirement	Implementation/Solution
Simplicity. Should easily fit into organizational procedures and work practices	Design a generic application that is easy to tailor for specific purposes, not offer everybody an extensive software package.
Simplicity. Little maintenance efforts for companies.	Web architecture design. Companies do not have to host their own servers.
Support documentation. Information should be easy to document.	Logging of messages and information. Database for work pictures.
Support management requirements for control. Avoid social fields and mistrust Scalability. Include different stakeholders on different locations to the system	Make a transcendent system. Every stakeholder can view relevant information. Web based solution. Mobile clients on both PDA and mobile phone/smartphone.

Figure 6.3: Contextual level requirements

different subjects of users and the goal of the collective activity. Usability and technology are the two categories within these individual requirements. Usability address in this thesis the relationship between each user and the application. Primary usability requirements are fast and simple applications that require few keystrokes. Regarding technology requirements, designers should use a smart client architecture. Mobile clients should be able to store data due to speed requirements and the possibility of being unable to connect to a server. At the same time, due to immature technology, the amount of data on a mobile device should not be too big, since loss of data is a potential problem in case of a crash. Therefore, different synchronization options should be offered the user.

The contextual design requirements are made up of the mobility and cooperation categories. Mobility is important to understand for designers, and a CSCW-application will be most purposeful in settings where the traveling modality is predominant. It is also important to know which influence the mobility has on employees in nomadic organization. In some cases, the management can have a mistrusting relationship toward their employees because mobile workers are invisible, and the management do not feel that they can control their employees. Mobility also makes employees individualists, and they do often as they please, as long as their primary work tasks are performed in a satisfactory manner. This kind of “anarchism” may be a hinder for CSCW-applications.

Cooperation may in light of this be hindered by the high degree of mobility. Another source of conflict is the division of labor. Not everybody is satisfied by the fact that more secondary work is imposed upon them, without receiving any benefits. Some of these requirements will be further explored in a scenario and prototype in the next chapter.

Chapter 7

Evaluating the prototype

This chapter first outlines a scenario based on the studied case studies, and the ideas that these studies produced. The scenario intends to visualize how work could be organized in a more horizontal manner than was the case in the studied companies. In addition, ideas to the functionalities of a future CSCW-application are suggested. Next, the chapter contains an evaluation of the prototyping, and the result of this work. Ideally, both scenario-based design and prototyping approaches are performed in close cooperation with users and the organization that are supposed to implement system. This has not been the case in this thesis, because it has been difficult to find participants that is willing to spend time on discussing and evaluating a prototype. The reason for using this approach, regardless of the existing situation, is discussed and justified in chapters two and four.

In addition, this thesis suggests that applications should be made rather generic, so concentrating on only one or a couple of users or companies would not contribute to a general result. The managing director of the software company also pointed out the importance of talking with a large number of users, and use the generalizations of these inquiries to make a product that addressed the core challenges. Functionalities that only applied to a limited number of users, would normally not be implemented in the Data Collector. It would cost too much to implement, and the product would be too extensive. As the construction site manager pointed out, for his company, big and extensive software packages were not attractive.

The scenario, outlined in the first part of this chapter, is based on the case studies conducted in this thesis, and is used to elaborate ideas to functionalities of a future CSCW-system. Some are inspired by the existing work practices, others are suggestions on how practices *could* be, in order to increase the efficiency of the organizations. As described in chapter two, describing a scenario can be a valuable point of departure for discussing ideas for the implementation of a ICT system, and how this can influence the work environment. Such a point of departure can be important when the management of a company is skeptical toward new routines and changes. The attitude of Tom in the plumbing company seems representative for other leaders in blue-collar companies as well; we know what we have, but we do not know what we get. The manager of Electro Company B also reported that they had had a wait-and-see attitude toward the Data Collector for several years. They had known about the product for many years, and just recently they found the solution “good enough”. Of course, describing a scenario is no guarantee for knowing exactly what a company gets from a system, but it can start creative processes of thinking new thoughts of organizing work. Since ICT may offer new possibilities, scenarios can be a valuable tool to display these possibilities for potential users.

The second part of the chapter, is an evaluation of the prototype developed from the results from case study analyzes and the outlined scenario.

7.1 The Workcoordinator

The Workcoordinator is the name of the application intended to be used in a future blue-collar scenario. The prototype is a rather simple and incomplete system, while the scenario tries to capture many of the functionalities that *could* be implemented. The scenario also gives ideas on how to deal with cooperation and mobility in a different manner, than was displayed in the case study companies. The Workcoordinator is founded on the following scenario, and assume that mobile workers are equipped with Java-enabled mobile phones or PDAs, while information in the office are distributed and received via web-clients on stationary computers or laptops. The functionalities in this scenario are summarized in a use case diagram in the appendix of this thesis, page 119.

7.1.1 The scenario

John is an electrician in the newly established electro company X. His assignments are located at private households, at a public institution and a construction project. He travels from home to the first assignment location of the day. The work plan for today was downloaded wirelessly on his mobile phone the day before. When he arrives at the location, he soon discovers that the work is far more extensive than the description of the assignment displayed. Two hours were allocated to this assignment, but it will probably take half a day. He starts the Workcoordinator on his mobile phone, and posts an alert-message that some of his other tasks that day should be assigned to available co-workers, or be postponed. The status of these assignments in the Workcoordinator are changed to open, and the foreman, Peter, in the office can see this on the assignment status page on the web-based part of the Workcoordinator. He can either delegate an assignment to an electrician that he knows has some spare time, or he can wait for an employee to pick up the assignment in case of an ad hoc-situation gives the employee spare time.

Back to John at his first job that day, he discovers that the car storage has run out of some standard materials which is required for the job. Again he starts the Workcoordinator, and sends a request for the locations of his co-workers. When he receives the answer, one on his colleagues is, according to the work plan, only one kilometer away, and he calls him to find out whether he can "borrow" some materials. This colleague is in fact finished with his first assignment, offers to drive by on the way to his new assignment, and John can continue his work on the location until his colleague arrives ten minutes later. Some time later he encounters practical problems related to the task, and he decides to ask for help. He takes a picture of the "problem situation" with his integrated mobile phone camera, and attaches it to a message shortly describing the situation. He then transmits it via the Workcoordinator. Some minutes later he receives a phone call from one of the foremen who explains the solution of his problem.

After the assignment is finished, John starts his Workcoordinator and checks the status of his next assignments in case some colleague has picked up one of the other assignments that day. The status of jobs may be "pending", "started", "needs help", "delayed", "finished" etc. In fact, all the assignments have been delegated to co-workers, so his plan is empty for the rest of the day. He then sends a request for open assignments, and he receives a list of three assignments with high priority. He chooses the one nearest by, but before he travels there, he wants to fill up the car storage. However, he is not sure which wholesaler (the company cooperate with three wholesalers) that carry the specific material he has run out of. Therefore, he starts the Workcoordinator and sends a search request on the wanted item. The answer shows that two of the wholesalers carry the item, and he chooses to go to the nearest one. At the wholesaler, his order is registered on the company and his employee number, and an eInvoice is sent directly to the company's economy system. Then he travels to the next assignment where he spends the rest of the day.

At the office, the foremen and work administrators receive orders from customers by phone. Either, an order is assigned directly to an electrician, or it is added to the list of assignments which workers can pick from, dependent on the priority of the assignment. The Workcoordinator located to the office is implemented with a web-interface, and orders are registered on the web. In order to make a transparent system, the management is also able to monitor the work plans for each employee, the status of their assignments, and view requests for help and assistance.

One of the foremen, Peter, receives a call from the construction site manager on the project that John is assigned to, and he wants to engage John regularly for some weeks. The manager only needs the electrician for some hours, and at various times, each day. Peter gives the construction site manager access to certain parts of the Workcoordinator system, by giving him an URL and a password. Then, the manager can use Workcoordinator to see when John is available the next weeks, and he can fill in a form on the web when he wants John to work at the construction site. The next time John is synchronizing his Workcoordinator he is made aware of the work at the construction site. He can choose to download the work plan for many weeks ahead, or only one single day.

7.2 Prototyping

As presented in chapter four, the goal of the prototyping was learning and evaluation of the elicited design requirements, thus, it was exploratory and experimental using prototype proper and breadboard prototyping. One goal of this learning, as pointed out in chapter four, is to evaluate whether prototyping can help us meet the criteria of good design. This is an attempt to meet Grudin's (1994b) sixth challenge for groupware developers, the difficulty of evaluation. "[P]artial prototypes cannot reliably capture complex but important social, motivational, economic and political dynamics" (*ibid.*, p. 100), Grudin claims. This thesis does not challenge this view, but proposes prototyping as a way to explore and evaluate especially individual design.

The Workcoordinator is a simple prototype, developed to examine some of the requirements, and evaluate these in relation to the theoretical findings of mobile cooperative work. The system consists of a Java MIDlet (described in chapter three), running on mobile phones, which communicate with servlets on a Tomcat/J2EE server. Data are stored in a SQL-database via the server. Information from the server is also accessible and possible to edit via the Internet. As stated earlier, the prototype is only a small part of what could be a larger system. Based on the case studies, some common and important features have been derived, and these were to be studied in the development of the prototype. In evaluating the prototype also common criteria of good design are used as measures.

7.2.1 Dealing with individual design requirements

The strengths of prototyping mainly come to light in dealing with the individual design requirements mainly, since these requirements deal with the interface and functionality layers, according to figure 4.3 on page 49. However, these will also influence the overall usability of a CSCW-system in an organization (Grudin 1994b), because a usable system on an individual level, will contribute to workers that really adopts the application. The requirements listed in figure 6.1 on page 87 were the focus of the prototype, especially interface simplicity and flexibility, and speed.

Developing interfaces

The interface was the first aspect to be investigated. The actual programming of interfaces in J2ME™can be done quite easily. Concerning the interface, it is earlier mentioned that mobile phones have a limited capacity for displaying graphics. This may both become a challenge and an advantage. The challenge may be to design something "flashy" if this is desired. The advantage is that the restricted capabilities make it fairly easy to decide which interface to create. Hjelm (2000) also calls for simple and straight-forward designs of interfaces without any extra effects. Figure 7.1 shows menus of the Workcoordinator. The source code is short and consists of a list of options and a couple of navigation commands. Different screens are made much in the same manner, and in the Workcoordinator each screen is located to its own class. Lists and commands are the main components in making the interfaces. If something has to be typed by the user, text-boxes are added. The prototyping of interfaces on mobile phones confirmed that J2ME™ can be a valuable tool for a dynamic design of interfaces. They are fast to program and easy to change in accordance to the need of new functionalities, changes in the handling and organization of information.

The portability of interfaces from mobile phone to PDA was not investigated. This is a technical programming issue, which not has been focused on, but it is still an interesting issue. Converter tools for programs from mobile phones to PDAs exist. For example, in order to run a MIDlet on

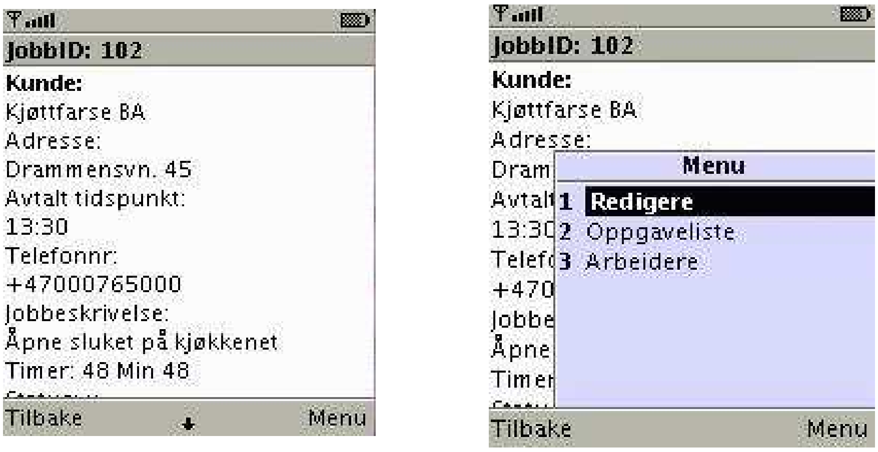

Figure 7.1: Screenshots

a Palm OS (see chapter three), the MIDlet must be converted to a Palm resource file (PRC) (Muchow 2002). A successful portability of code from mobile phones to PDAs could say something of the scalability of the system. An argument for the scalability of the Workcoordinator is the web-interface for stationary users (or laptops). Being such a large network of cooperating actors as the blue-collar environment, using a web-based system should ease the process of including wholesalers, project managers, other companies and blue-collars and other potential actors in the cooperating network supported by ICT. This is described in the last paragraph of the scenario.

Developing functionalities

Moving down one level in figure 4.3 page 49, functionality is the next issue to examine. In prototyping functionalities, the technological constraints come more into the light. Outlining a scenario, such as the one in section 7.1, can be valuable in defining the core functionalities. A UML[1] case diagram, page 119, was also drawn to illustrate potential functionality. As discussed in chapter three, the ideal architecture of a CSCW-application should be a smart client architecture. Thus, two important features are the foundation of all functionality on mobile devices; the possibility of both transmitting and storing data.

These fundamental functionalities were explored in the prototype. Programming these functionalities for the mobile client posed no big challenges technically. The primary challenge is to organize data properly in

[1]Unified Modeling Language: http://www.uml.org. Accessed May 10th 2004

order to minimize the existing constraints of low bandwidth and limited size of memory. One should allow the application to use approximately 100kB of the mobile phones' memory, but this can be hazardous, because users may have various other applications on their phone that limits the space for the Workcoordinator. In the prototype, the data of one assignment was estimated to contain approximately 2000 characters, that is 2000 bytes, so the memory should be able to handle 50 assignments which seems more than adequate. In a "proper" system, the amount of data would probably exceed the 2kB, but still 100kB seems adequate. One should also consider the time requirement in aiming to handle the data as effectively as possible, since the mobile phone uses time to write and read from memory.

The time requirement is also existing in the handling of data that are transmitted wirelessly. Even though a connection is easily established between the mobile client and a remote server, the main challenge is to limit the time used on transmitting the data. Connecting and even transmitting a small amount of data exceeds 10 seconds, and often 30 seconds. Thus, mechanisms for an effective download and upload of data must be developed. For example, let the user decide the amount of data, and which data should be updated in the synchronization of assignments.

At first look, the J2ME™ would mainly address usability and technological requirements, and most of this discussion is related to the human-interface interaction of the prototype application. Still, there are things to mention about contextual and groupware requirements as well. The possibility of applying the nearly identical source code for both mobile phones and PDAs, makes the J2ME™-platform versatile. The micro edition is also part of the big Java-family of application- and web-services solutions which offers a seamless package that integrates possibilities for accessing data from both web-browsers and mobile devices.

7.2.2 Dealing with contextual requirements

"Group activity is difficult to study and characterize" (Grudin 1994b, p. 99), because there is often a gap between the way work is supposed to be carried out, and how it actually is done. Unforeseen situations occur, and often much work activity is dedicated to exception handling and improvisation. As the scenario in section 7.1 describes, the Workcoordinator is designated to help handling exceptions, for example, in case of a too extensive assignment. However, the ICT tool may also become a source for exceptions, or breakdowns. That is why it should be purposeful to discover potential breakdowns in the activity systems both regarding individual and contextual issues.

In addition to gain a good understanding of the work environment in order to meet contextual requirements, the process of designing a CSCW-application should also aim for strategies to easily change system features. The chances for new and other requirements are high when the uncertainty of the application domain is also high. Creating *flexible* and *comprehensive* system structures are two classic criteria of software quality (Mathiassen, Munk-Madsen, Nielsen, and Stage 2000), that can support a dynamic development of CSCW-application. This can be done by using a component architecture.

> A component architecture is a structural system view that separates system concerns. A good component architecture makes a system easier to understand, organizing the design work and reflecting the stability of the system's context. It also transforms the design task into several less complex tasks" (*ibid.*, p. 189).

The prototype was developed with a component architecture in mind. For example, the interface consists of a range of different screens. These are managed by a Screen handler, which takes care of the "browsing" between screens. In this respect, prototyping was proved valuable. For example, one connection handler, which takes care of the connection between the client and the server, was made, and this works regardless of which request is made to the server.

This does not directly address how coordination and mobility is organized in companies. But, since coordination and mobility in terms of contextual design requirements make the design process uncertain, this uncertainty can be met with measures of following criteria of good design. That is, a component based architecture makes it easier to develop dynamic systems, that is easy to understand. The prototyping showed that exploring such components is purposeful, and can meet the requirements of a dynamic design process. Using an object-oriented programming language such as Java and J2ME™ supports this component architecture.

7.3 Requirements in terms of software quality

In this section, the criteria of software quality listed in figure 4.5, page 50, are discussed in relation to the elicited design requirements and the prototyping. The motivation for this is to comment on whether the requirements, elicited from case studies and examined in the prototype, can contribute to the quality of a future CSCW-application. The problem and application domains are previously described as complex, and this complexity brings high uncertainty into the design process. If requirements and prototyping meets criteria of software quality, this may suggest a lower uncertainty regarding the design of the CSCW-application.

Usable

"The system's adaptability to the organizational, work-related, and technical aspects" (Mathiassen, Munk-Madsen, Nielsen, and Stage 2000, p.178). Usability has been a key issue in this thesis, constituting one of the pillars in the design of a CSCW-application. The concept of usability is narrowly interpreted in chapter five and six. However, nearly all of the design requirements of the CSCW-application address either organizational, work-related and/or technical aspects.

Secure

"The precautions against unauthorized access to data and facilities" (*ibid.*). Even though being an important issue, this has not been the focus in this thesis. It is mentioned as an issue if a mobile client is lost or stolen. Then accessibility from this device can be shut off the central system. This is no technical challenge, and a prototype is not needed for examining such a functionality. More detailed descriptions of security measures is a matter of more technical issues than the scope of this thesis.

Efficient

"The economical exploitation of the technical platform' facilities" (*ibid.*). Prototyping with J2ME^{TM} can be done fast and at low cost. Even with medium programming skills, it is quite an easy programming tool to work with. It is also easy to deploy applications on mobile phones, and today all blue-collars and customer consultant own a mobile phone even though not all of them are Java-enabled. Thus, developing a CSCW-application for mobile phones would not require great financial efforts.

Correct and reliable

"The fulfillment of requirements" and "[T]he fulfillment of the required precision in function execution" (*ibid.*). The prototype does, for example, not meet the requirements of speed, that is, the application deployed on the mobile client is too slow. This may be the result of programming algorithms or the specific phone that was used for testing. However, it is such a serious problem that the problem must be overcome before a full-scale project is initiated.

Maintainable

"The cost of locating and fixing system defects" (*ibid.*). In order to obtain this criteria, the application is developed in a component-based fashion. Errors are easy to locate. Problems with the connection functionality can be located to one of the classes in the Connection component. Regarding the interface, each screen is implemented in a class, thus, finding the specific class that is to be changed is easy. Following the design structure of the prototype should result in a maintainable system.

Testable

"The cost of ensuring that the deployed system performs its intended function" (*ibid.*). This is, according to Grudin (1994b) one of the hardest criteria for groupware to obtain, because of all the obstacles of a meaningful, generalizable analysis. The work of this thesis also showed that it may be hard to find companies to test a system in. Therefore, prototyping is proposed as a mean to test some key features of a system. If these tests fail, the problems should be solved before designers move on to make a full-scale product.

Flexible

"The cost of modifying the deployed system" (Mathiassen, Munk-Madsen, Nielsen, and Stage 2000, p.178). The component-based architecture of the system should provide a flexible system. The prototyping can be used to fully develop a component and test this without having to implement the whole system

Comprehensible

"The effort needed to obtain a coherent understanding of the system" (*ibid.*). Because the component-based architecture is kind of a divide-and- conquer strategy, this should make the prototype and a future system comprehensible. Interface and functionalities are treated in respective components. Thus, in order to understand it and get an overview, it is sufficient to know the components and how they relate to each other.

Reusable

"The potential for using system parts in other related systems" (*ibid.*). Much of the prototype code could be used in a full-scale system. It is also preferable to make components generic, so it is possible to use these in other systems. For example, the connection component. This can be used in most systems that need wireless connection.

Portable

"The cost of moving the system to another technical platform" (*ibid.*). In this thesis, the option of moving Java MIDlets from mobile phones to PDAs has been presented. This can be done at low costs. Working with Java requires that clients have a Java Virtual Machine (JVM or KVM, ref. chapter 3). Mobile phones and PDAs that do not allow this cannot be used for this system.

Interoperable

"The cost of coupling the system to other systems".(*ibid.*) J2ME™can be coupled to different servers, both Java-based servers such as Tomcat/J2EE and Windows .NET. Thus, using J2ME™on mobile clients do not prevent designers to use other common technologies on the server side. This is not much explored in the prototype, but is a valuable feature according to Grudin (1994b). In order to justify the purchase cost of a CSCW-application, it should be able to integrate it with existing systems. J2ME™on mobile phones could for example be integrated with the Data Collector system as a coordination feature.

7.4 Summary

This chapter has presented the Workcoordinator application, based on both case studies and discussions from chapter five and six, and literature studies.

First, it can serve as a proposal to new ways of dealing with mobile cooperative work. This must not be interpreted as a view that companies should change their work practices only because of new technology. Maybe cooperation won't result in more efficient work routines. But this application shows that there is technological possibilities for doing things differently. Second, the brewery company case showed an organization that was willing to invest time and money in ICT, and change the work routines of employees accordingly. In their view, it makes the organization more flexible and cost-effective. In larger companies with many mobile workers, an application such as the Workcoordinator may be considered valuable.

Applying J2ME^{TM} in building applications and systems for this purpose is found valuable both from a company view and a developer view. It is easy to build a seamless solution using different parts of the Java technology, making information accessible from both web pages and mobile devices. J2ME^{TM} also makes development fast because it is easy to make standardized packages and solutions. Prototypes can be made easily and with limited resources.

Applying prototyping can be a valuable method for endeavoring to meet the criteria of software quality. The relevant criteria in the evaluation of the prototype was usable, efficient, maintainable, flexible and comprehensible. The prototype was directed at fulfilling these criteria, and did so to a large extent. A requirement that was not fulfilled was correct and reliable, since the application does not run fast enough.

Chapter 8

Conclusions

This thesis has presented and described a process of eliciting design requirements for ICT that intends to support cooperation in nomadic work environments. The thesis suggests means of enhancing cooperation as well, because ICT offers solutions to overcome the earlier barriers that geographical mobility poses on cooperation. Suggestions and advices to the design requirements of ICT in order to support mobile cooperative work is based on six case studies which are analyzed with the purpose of identifying breakdowns in an activity system. Suggestions to functionalities of a CSCW-application and organization of work practices are exemplified in the outlined scenario and evaluated prototype.

The conclusion is organized as follows; First, problem definition number one (page 6), the important features of mobile cooperative work, is answered, based on the results of the case studies and the analysis of the findings presented in chapter five (pages 53-78). Second, problem definition two is concluded in section 8.2 when it comes to ICT design requirements presented in chapter six (pages 79-94). Third, how an ICT application, exemplified in the Workcoordinator in chapter seven (pages 95-106), can enhance cooperation in mobile work situations is answered in section 8.3 along with the conclusion of the evaluated prototype.

8.1 Mobile cooperative work

This thesis discovers three important features of mobility and work practices in a traditionally nomadic work environment. First, the geographical mobility and patterns of movements are results of a world without ICT, that is, many work practices were established centuries ago and seems inflexible today. This means that much traveling is related to secondary work that could be performed or organized otherwise, and more effectively supported by ICT. Second, workers that perform assignment-based work have an individualistic attitude toward their own work. They alone are responsible for carrying out the primary work, and most of the secondary work as well. The organization of work is centered around assignments, and as long as these are performed adequately, workers are free to organize their own work routines as it suits them. Workers are also “allowed” to do this since they are invisible to the management of the companies, and cannot be monitored, most of the time. Third, managements of companies are aware of this, and are to a great extent dependent on the trust between themselves and the employees. However, in two case studies, management reported, directly or indirectly, mistrust toward employees. In both companies, the Data Collector was used for measures of control toward employees.

Designers of CSCW-applications must be aware of both workers’ individualism and managements potential mistrust toward “invisible” workers. If individual workers do not adopt a positive view of the application and do not see their own benefits of it, the chances for users avoiding it are big. The managements need for control must also be considered, also because they always take the final decision in implementing a system. A system that is based too much on horizontal peer-to-peer communication will probably discourage managements to implement such a system, because they will feel even less in control of their employees.

Both vertical and horizontal cooperation were discovered in case study companies. Vertical cooperation is present in all the companies, and some had a more strict vertical and hierarchical organization than others. In one company horizontal cooperation was deliberately restricted by the management, fearing that letting the employees organize anything would lead to chaos. This thesis suggests that this is a result of social fields and invisible workers. Another important aspect of the introduction of ICT and cooperation is the division of labor. The implementation of the Data Collector showed that workers regarded this as extra work and responsibility, regardless of the fact that Data Collector is meant to substitute paper. Presumably, we should think that the workload of registering something on paper or in the Data Collector was close to equal. However, it has meant additional work according to employees, but we could not find any strong negative opinion against Data Collector as a result of this.

This thesis suggests that the reason behind the large proportion of vertical cooperation, is mobility and lack of means, such as ICT, to support horizontal cooperation. Since mobility creates social fields, managements are interested in organizing work vertically in order to maintain control. The earlier lack of channels to communicate horizontally has also constrained horizontal cooperation. The brewery is an example of a company that sees the possibilities of ICT and potential in organizing work more horizontally and network-like. This is not the case in the studied blue-collar environments, even after implementing the Data Collector. However, this thesis claims that there is such a potential in blue-collar environments as well.

8.2 Application design requirements

By analyzing the studied companies in an activity system, four main categories of requirements are derived from this analysis; *usability*, *technology*, *mobility*, *cooperation*. The object of the collective activity is to process all information, that is the required secondary work, in order to complete an assignments. By distinguishing the already existing or potential breakdowns of this activity system, design requirements are elicited from these breakdowns in order to overcome and solve existing and potential conflicts, that may hamper the collective activity of cooperation.

Focusing on usability is vital in order to succeed in designing systems for such work. Usability is in this thesis limited to the interaction between the user and the device. As Grudin (1994b) claims, the success of a CSCW-application is dependent on a critical mass of users in an organization, that is, if half of the employees in a company do not use it, the organizational usability of the application diminish. This becomes especially critical in mobile settings, because as described in the previous section, mobile workers can in a less degree be monitored or controlled, and therefore adopt their own working habits. If breakdowns regularly occur in their interaction with an application, they will most likely avoid it. Then the application will impede the cooperation, not support it.

Usability requirements address specifically time and simplicity aspects. The interface should be easy to understand, there should be little need of input writing, and the application should be fast to use. According to the managing director of the software company, who has introduced the 10-second rule, claims that the patience of blue-collars is fairly limited. The empirical material of this thesis supports this view.

Technology is the second category to focus on. This thesis proposes a smart client architecture in a CSCW-application, and this is primarily because of technological conditions. Both theory and empirical material suggest that mobile ICT still is immature when it comes to network capacity and general performance of mobile devices. The limited net-

work capacity makes it purposeful to design storage functionalities, but since there is a definitive risk of data loss related to the unstableness of mobile devices, these should be synchronized regularly with the remote server.
Mobility is the third category, and requirements within this category try to solve the core challenges that the features of mobility, outlined in the previous section, pose. In addition to support horizontal communication, the system should be transcendent in the sense that management should be able to read messages and requests from employees using the application, and be able to monitor the progress of assignments. Workers' individuality must be dealt with using the previous mentioned usability requirements. In addition, organizing workers in networks may also enhance cooperation an increase efficiency.

Cooperation is the fourth category, and requirements within this category, should address both vertical and horizontal cooperation. For example, relevant information should be retrievable for all employees in a company, both from mobile clients and stationary computers in the office. Focusing on the previous mentioned usability will hopefully also prevent users to experience such an application as an unreasonable extra workload. In addition, if work is organized such a way that workers can see their benefits, this will promote the use of a CSCW-application.

8.3 The scenario and prototype approach

The scenario of the Workcoordinator, an application for supporting mobile cooperative work, has had two purposes. First, based on the conducted case studies, the scenario suggests how work *could* be organized otherwise in the blue-collar companies with the aid of such a CSCW-application. In this scenario, workers are to a larger extent organized in a network, seeing co-workers as each others' resources in cooperating more flexible. Even though this thesis does not focus on design of work and organization, it suggests that enhanced cooperation supported by ICT may increase the efficiency in work practices. The scenario visualizes many of the ideas that the work with the thesis has produced, and it makes it possible for potential users to evaluate these ideas. Second, the scenario outlines some functionalities, also summarized in a use case diagram on page 119, which seem purposeful in a CSCW-application. Further, some of the functionalities in the scenario are explored in a prototype.

Since the purpose of the prototype is learning and evaluation, an exploratory and experimental type of prototype is applied. The conclusion of the prototyping is that it is good way of exploring the elicited requirements. Using prototype proper gives knowledge to the design of interfaces on a horizontal level. This proved to be a quite easy task, that contributes to a dynamic process of designing interfaces, that is, changing and making adjustment are fast and easy to do. Using breadboard prototyping answered technical questions, for example, related to the fastness of the application. Regarding the 10-second rule, testing showed that the application deployed on a mobile phone does not run fast enough for such a requirement. The prototyping shows that especially the time requirement is hard to fulfill, and is important to focus on, since its significance is underlined by many participants in the case studies. The reasons behind the slowness of the application is not deeply investigated. The programming algorithms may be inefficient, or the mobile phone testing device is inadequate.

On a meta-level, questions can be raised whether it is correct to apply scenario-based design and prototyping in a situation where users are not included in the process. This thesis suggests that this approach is purposeful for the developer when it comes to evaluating and learning from the developer's own requirements.

8.4 Further research

Since the problem domain of this thesis is rather complex, the thesis has attempted to unite several different areas of research, and to keep a focus on both technological and contextual aspects of the design process. A result of this may be that each area of research is not treated thoroughly enough, and should deserve closer attention in further research.

Further research could be continuances of both problem definitions, since features of mobile cooperative work is a large field of research. This thesis does not make any generalizations to other nomadic work environments than the ones studied. It is even careful in generalizing to other blue-collar companies as well. Other professions and nomadic environments can in further research be studied. Comparative studies can be made with workers who do not have been mobile "always" such as the blue-collars and salesmen. A hypothesis could be that "new" working nomads will easier adopt mobile cooperative work, for example, if their old work routines are not founded on mobility. A more theoretical approach could also examine whether the empirical material in this thesis challenges or support existing literature and theory.

Designing a CSCW-application in itself is a more comprehensive process than this thesis aims to capture. Different approaches to and stages of this process should be studied further. A more technological approach could compare which technologies are the better suited for CSCW-purposes, for example, Windows CE versus J2ME^{TM} could be examined and compared. The prototype could also be explored in a real-life setting if a company willing to participate in this was available.

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Appendix

Workcoordinator Use Case