Work in Motion: Interpretation of Defects along the Roads

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Abstract. This paper reports findings based on an ethnographic study of an occupational group, the road inspectors, at the Swedish National Road Administration-Production. We examine current work practice where the inspectors conduct a truly mobile work, since they are constantly on the move. It is not a fact of movement between different work places, seeing that the continuous movement could be understood as the work itself. The simultaneous tasks to perform create a complex environment to support with information technology. Our suggested design implications focus on the support of manual work, integrating loosely coupled methods of recalling, delegating, and informing about actual contingencies. The results will be used to inform a redesign of the current system, to integrate informal actions into the formal reporting tool. Except from contributing with design implications, we do also add relevant aspects regarding different modalities of mobile IT-use described in an existing theoretical model.

1 Introduction

Mobile devices such as handheld computers are becoming more commonly used in various situations supporting mobile workers. When developing this kind of tools several problem-areas arise, for instance, the identification of which tasks to support, or how to benefit from users' mobility. In many cases the phase of designing and inventing future applications seem to be lacking in investigating today's user practice before developing new innovative concepts. The starting point is based on technological prerequisites rather than current work practice. This is exemplified in *Plans and Situated Actions* written by Lucy Suchman [Suchman, 1987], where she explored the usage of a complex photocopier. Even if her research was conducted in a stationary setting we argue that corresponding examples occur in mobile settings. To approach this dilemma further, we chose to conduct an ethnographic field-study of today's work practice. When initiating this study we were deliberately searching for a research context outside the centralised control rooms. We had a genuine interest in occupational groups acting on a local level, far from the centralised monitoring of activities. We chose a group of road inspectors at the SNRA-P (Swedish National Road Administration-Production) [Esbjörnsson, 2001]. This occupational group plays a major role in the road maintenance management, while they keep track of all changes in the road network. When performing their tasks they spend most of their time alone inside a truck, driving at least 150 kilometres each day. To keep order on the tours of inspections, and all identified defects identified along the roads, they use a system with mobile computers connected to GPS-receivers (ProData). The system in use has been a natural working tool for the last 2 years, and now they are engaged in a process of discussing further development of the system. The results from this research project will influence forthcoming decisions regarding additional functionality.

The purpose of this paper is to explain the complexity of the inspectors' work, examining subtasks of their inspections along the roads. The complex rules they apply while on the move, a truly mobile working situation. The identified breakdowns will be used to inform the design of a prototype improving the existing system, supporting interpretation work. This application-oriented approach [Ljungberg, Dahlbom, Fagrell, Bergqvist & Ljungstrand, 1998] has turned out to be a successful research-method when identifying new applications supporting mobile collaborative activities. One example of research conducted this way is the doctoral dissertation by Fagrell [Fagrell, 2000B]. Except from designing a prototype, we use our experiences from the fieldwork to inform the development of an existing model [Kristoffersen & Ljungberg, 1999A] describing three modalities of mobile IT-use.

We start the paper by introducing earlier ethnographic fieldwork carried out in settings where mobile IT has been used (section 2). The following sections describe the research context of the study (section 3 and section 4). In section 5 we report findings from the empirical fieldwork, and in section 6 we discuss implications, which will influence redesign of the existing system. In the last section we conclude the paper.

2 Mobile work

During recent years there has been a strong tendency to focus on mobility in IT-research as well as in IT-industry. Initial applications have consisted of common systems from the stationary setting, which have been converted into the mobile setting, such as calendars, phone books and lightweight versions of office-applications. These examples are very general, and the major user group is people working with administrative tasks. In our work we have chosen to explore another type of setting, which could be considered as dull and unattractive, but still very high-tech and fairly impressive regarding usage of mobile IT. We will give some examples on different settings, outside the office, which have been explored. Earlier research concentrating on distributed mobile IT-work has been focusing on process engineers at wastewater treatment plants [Bertelsen & Nielsen, 1999] [Nilsson, Sokoler, Bindner & Wetcke, 2000], news journalists [Fagrell & Ljungberg, 2000A], service technicians [Wiberg & Ljungberg, 1999], construction site workers [Luff & Heath, 1998] and snow crew at an airport [Juhlin & Weilenmann, 2001]. In our overview of the projects we deliberately concentrate on the mobility of people performing work, and not the objects they are working with.

The two studies performed at the wastewater treatment plants give a good example of work performed in a distributed setting. Still this setting is limited by the size of the plant, and the spots of interest are the physical equipment purifying water. Their main task is to keep the plant running, and this is done by inspecting and repairing the machines. The process engineers perform the work by taking inspection tours, by *walking* around in the physical setting, and supervise the plant by computer monitors (digital representation). Most important is the spots where defects occur, and the places where they meet colleagues during the working day. The researchers do also imply that work is performed in a collaborative way, since the engineers cooperate to solve problems.

The news journalists studied by Fagrell [Fagrell, et al, 2000] perform their working tasks under different conditions, even if they represent a group of mobile workers supported by IT. Their working area could be considered as distributed over a wide area, without definite borders. The object of interest is people they will interview, or events they are supposed to cover. These people, or events, could be situated anywhere, and the journalists need to *travel* to meet them. To organize the work the journalists cooperate to solve their daily task and to coordinate their activities, to produce a radio programme filled with news.

The service technicians [Wiberg, et al, 1999] do also conduct work in a similar way, since they perform actions in connection with the equipment that needs to be repaired or adjusted. Considering this strong connection to physical equipment located in the area, the mobile technologies do not bridge the gap between performing work anytime and anywhere. They have to be in the right place to have the possibility to conduct repairs. They are *travelling* to move to the distributed working places, where errors have occurred and have to be mended.

Another aspect of mobile work is viewed in the study of the construction site workers [Luff, et al, 1998]. The occupational group spend a longer period of time in the construction site area. Of course they are mobile in this limited setting, but still the movement is bound to the construction site. This phenomenon could best be described as that they are *visiting* the working place during a limited period of time.

All these examples fit into a model presented by Kristoffersen & Ljungberg [Kristoffersen, et al, 1999A]. They introduce a basic reference model explaining the research area *mobile informatics*. Three different modalities are used to conclude the different modalities of mobile informatics. The categories used are *travelling, visiting* and *wandering*. *Travelling* is the process of going from one place to another in a vehicle, a movement between different locations. *Visiting* is spending time in one place for a prolonged period of time before moving on to another place. *Wandering* is extensive local mobility in a building or local area.

One of the research projects mentioned above does not fit into the model proposed by Kristoffersen & Ljungberg. This case introduces another aspect of mobile IT-use. The project in mind, the snow crew at the airport, performs simultaneous activities since they are moving while working. The moving is more than an issue of moving to a different place of work – it is the work itself [Juhlin, et al, 2001]. As in the other cases presented, the main working tasks occur in the physical world. This is one of the main features with mobile IT-use, the tasks that occur outside the computer is the primary working task, otherwise the need to be at a geographical spot would be irrelevant. Kristoffersen propose that 'users may be involved in tasks ("outside the computer") that demand a high level of visual attention (to avoid danger as well as monitor progress), as opposed to traditional office setting where a large degree of visual attention is usually directed at the computer' [Kristoffersen & Ljungberg, 1999B].

3 Ethnographic fieldwork

There is a growing recognition that a detailed understanding of users practices is essential in determining requirements of new technologies. As such ethnography is increasingly being linked with the technology development process. In this case our focus is mainly to understand and describe the complex environment of the inspectors, but we do also have an interest in informing the process of identifying new services.

Ethnography was originally developed within the area of anthropology as a method to gain insight into the cultural practices of societies. When used in the area of system development, the technique could be seen as a way of gaining insight and understanding in everyday practices [Hughes, Randall & Shapiro, 1992]. The fast growing body of ethnographic research and its popularity in CSCW is explained by the need to account for problems with the use on information systems, as well as demands to understand social interaction when designing mobile information technology [Heath & Luff, 2000]. It is central in ethnography to see users' activities as actions within a socially organised sphere [Hughes, King, Rodden & Andersen, 1994A]. Due to the familiarity of their everyday situations, many activities considered as important are often taken for granted by those who perform them. Subsequently it is not sufficient to simply ask people about their practices. Furthermore, people generally find it difficult to articulate their knowledge, describing their way of performing tasks [Hughes, et al, 1992]. Therefore, in addition to interviews, ethnography relies on observations. In systems design several ethnographic approaches are used. In this project we apply the "quick and dirty" approach [Hughes, Sharrock, Rodden, O'Brien, Rouncefield & Calvey, 1994B], where the fieldwork is conducted during a limited period of time in order to inform the design in the initial phase of the development process.

The research presented in this paper constitutes an introductory phase in the project and will later be followed by development of new prototypes and evaluation [Ljungberg, et al, 1998]. The prototype developed will be brought back into the setting of the fieldwork, where it will be introduced and used over a period of time. This process will be supervised by the researchers and be a part of the evaluation, which will inform continuous development. The researchers double competencies, consisting of experience from the fieldwork and familiarity with new technical possibilities are a basic condition in this work. The research is conducted in an interdisciplinary environment, working as a base for generation of ideas for future services. The result from the initial phase of the project is visualised through the formulation of use suggestions, and the development and design of prototypes [Dahlbom & Ljungberg, 1999].

We participated in the inspector's work by following them in their daily tours of inspection. Five different inspectors, belonging to three different local offices, have been studied during a period of 10 days. While the inspectors conducted their work, we participated by sitting in the drivers' cabin. Except from the conversation with the inspectors during the tours of inspection, we did also participate in three morning-meetings at the office. During the fieldwork we took careful notes, which later has been transcribed. In the analyse-phase we coded the transcripts to identify patterns in the inspectors' work.

4 The road inspectors

This section introduces the occupational group and the working tasks. This is done in order to understand the complexity of the working situation.

4.1 The road inspector

The inspector spends most of his working day alone inside the cabin of the truck. However, the individual work is based on collaborative decisions and shared knowledge. There is a need to communicate with colleagues to stay updated on the status of the road network and to share a common understanding regarding their tasks. There are also interactions with people outside the organisation e.g. the police or the Traffic Information Central (TIC).

An inspection tour lasts for 150 to 250 kilometres. The inspectors are patrolling the road-network according to a predetermined schedule. The periodicity of the inspections is determined by traffic flow and road size. Main roads in the region are inspected every other day, minor roads with less periodicity. Essential in these tours are the visual inspections and repair of urgent defects. The defects are best described as anything occurring on the roads, or in the vicinity, influencing the road users. Some examples on different types of defects could be everything from illegal road signs, worn roadway, dead animals, to abandoned cars. These tasks are all explicit regulated in a contract with the orderer, and mediated to the inspectors by a manual in each truck.

A major part of the inspectors' time is spent seated in the cabin of the truck, where most of the IT is attached. The inspector is surrounded with a large palette of technological equipment when he is in the driver's seat such as FM-radio; communication radio (UHF); ProData, and a mobile phone equipped with a headset. The FM-radio is a source of local traffic information. Mobile phones are used to inform colleagues about local contingencies and to delegate tasks. ProData is used when conducting formal reports.

During inspection, the ProData-system consisting of a mobile computer connected to GPS-receiver is the main tool to gather information. The contractor develops the system together with a consultant company specialised on geographical information systems. The GPS-receiver automatically logs the position during the inspection, and all defects reported by the inspector will be linked to the correct position. The defects should be reported, irrespective if they are repaired or not. The log created by ProData will verify that the roads have been inspected according to the contract.

4.2 Working tasks

In everyday work, the inspectors conduct several activities. Basically, the work consists of three different tasks, which are clearly identifiable in the following example.

> We are driving on a highway heading north from Stockholm City. The inspector sees a badger lying dead on the road and he presumes that a car has hit it. It is lying in the proximity of a bus stop. He halts the truck and turns the hazard-warning flasher on. Then, he types a short defect-code, indicating dead animals on the roadway, into the computer and adds the text "badger." He says that he normally enter a text describing the dead animal or the defect. When this is done he leaves the cabin and shovels the dead badger into the ditch.

The example starts with the inspector driving his predefined route. Suddenly, while driving, he *identifies* a defect, a dead animal on the roadway. Then he *reports* the defect. In this case he fill the forms provided in ProData. He uses a combination of a predefined defect code, which is documented in a manual present in the vehicle, and his own textual input. The positioning system (GPS) forces him to be at the correct geographical spot when reporting. Otherwise the automatically generated position-data will differ from the position of the defect. Then, he leaves the cabin of the truck to take care of the defect, i.e. *repairing* the road. In this case the identification of the defect took place as a very straightforward activity, but more commonly this could be a troublesome procedure.

5 Identifying defects

In many occasions neither the identification, nor the appropriate representation when reporting, is as evident as in previous example. On the contrary, it often takes the skill of the inspector based on the ability to interpret contingent situations and conduct successful collaborations, to make the appropriate judgement of how to apply the manual in a specific situation. It can for example be difficult to decide if the defect is placed in the physical area of their responsibility. Signs along the roads could either be illegal or have a dispensation, missing signs is difficult to discover without local knowledge. Some of the objects are slowly becoming defects, while other defects occur instantaneously.

In the continuation of the paper, focus will be on the phase of identifying possible defects. This phase is considered as the most complex part of their work, consisting of ongoing identification and interpretation of possible defects along the roads. The following paragraphs introduce experiences from the fieldwork.

5.1 Colleagues describing and delegating

Occasionally identified defects are passed on to colleagues to conduct repairs. This occurs when particular equipment is needed, or when tasks don't have immediate priority.

> One task he has been instructed to take care of is a cable above the asphalt (one of these cables detecting incoming cars in the proximity of the traffic lights). A colleague discovered the defect at the end of last week, and now it has to be mended before it is broken.

This excerpt exemplifies collaborative aspects of their work. Tasks identified could easily be delegated to colleagues. This procedure of delegating tasks is performed with a plethora of different methods, handing over post-it notes, verbally during meetings or by the use of mobile phones. Regardless of method, the complexity of position descriptions remains, since all methods are separated from the actual place of the defect. The inspector who receives the task will get a description of where to find the defect. Still he has to find the place and identify the defect before conducting the repair. In the case described above, the defect wasn't repaired during the inspection tour. Presumably the task was forgotten, since the inspector was not reminded when in the vicinity of the, earlier, identified defect.

5.2 Interpretation of an abandoned car

The interpretation of possible defects is a complex activity. For example, it can be difficult to decide if a defect is placed in the physical area of responsibility. Some road signs could either be illegal or have a dispensation during a limited period of time. Some of the objects are slowly becoming defects, while other defects occur instantaneously. In the following case, the inspector is faced with the problem of deciding if an object (a car) should be understood as a defect or just part of normal road use. We are driving on a motorway north of Stockholm. A red Mazda is parked at the roadside:

> [Inspector]: I have not seen it before, so I will report it. If it's still here on Wednesday I'll do it. The owner may be at the gas station, but it looked quite nice. Perhaps it is gone by then. It wasn't rusty. It's troublesome that we cannot remove the left cars. The police have to contact the owner as long as it isn't placed dangerously to the other road users, and the police seldom do this judgement.

The inspector is weary about the interpretation of the car. He is quite clear about the object as newly getting there. Thus, it has not been reported earlier on. But as soon as he decides to report the object, he postpones the activity until he has more information.

If he waits two days, and the car is still there, it is more probable that it really is a defect, i.e. an abandoned car. In this situation, he interprets the wear on the car to get indication concerning its status. If it is rusty it is more likely that it is abandoned. New cars are seldom left alongside highways according to this way of reasoning. Thus, individual identification of defects demands interpretative skills of the inspector.

5.3 Exemption handling

The former example indicates certain guiding principles applied when interpreting the environment, the inspector has a "feeling" for what could be considered as normal. In the following example the formal rules has been replaced with temporary regulations.

> Like the other road inspectors, Einar finds it hard to be consistent. In some cases Richard has made a dispensation for certain signs, which could be difficult to know. In cases where he is uncertain he calls Richard to check with him. Most often there is a compromise between how disturbing the sign is, and which event it is connected to. It is obvious that they want people to come to their events. In most cases this will be more obvious in smaller villages, compared to the big cities. Most often they try to inform each other. When Richard has given an exemption, or one of the superiors, they write a document that could be shared among them. In the end they have to keep the information in their mind, while driving. It doesn't occur that they start the working day by logging into the stationary computer.

Even if the rules are formalized and spread in the organization there is a factor of uncertainty since these exemptions are being made. They are trying to share the information by the use of documents, and except from these they inform each other during meetings, and use the phones to sort out the question, when in the vicinity of the signs. Occasionally they do not reflect over the signs placed by the roadside, they have other tasks to aim their concentration on. The document at the office will not be to any help while on the road.

5.4 Interpretation as a social activity

Further, when the inspector identifies an object as a defect he has not only to consider the formal manual and compare it visually with his environment. He also has to consider information given by his colleagues. They could tell him if the object has received a special status as a normal object rather than a defect. The following example shows that interpretation of objects is both an individual and collaborative task.

> While we are heading into a short tunnel, the inspector discovers a sky-lift placed in a lane in the other direction. He concludes that the workers don't follow the safety rules, since a required type of equipment is missing (a truck with a bumper in the back specially designed to resist a crash from behind). As soon as we passed the tunnel, the inspector returns to talk

> with them. He is not happy since they are only using temporary signs showing that one lane is closed, and not the dynamic sign placed just outside the tunnel. He decreases the speed of the vehicle and lowers his crash-shelter and lights the hazard warning flashers. Finally he stops just back of their vehicle. He leaves the cabin of the truck for approximately three minutes. When he returns he had found out that they didn't have the proper documentation (the traffic appliance plan) showing that they were allowed to work at this site. In theory, the documents must be formally approved by the road administration, and consist of all information connected to the planned work. There should be information about people responsible for the task, what they are supposed to do, which level of safety, for how long time the work should continue. However, the person responsible for the work was away for the moment driving the vehicle equipped with the crash protection device. The inspector makes an immediate call to the traffic management centre to control if they are informed. The person answering at TIC doesn't know what is going on and asks his colleague who don't know either. They have no documents that seems to correspond to the time and task. They complained about the organisational procedures and concluded by saying that nothing could be done at the moment. The inspector didn't write down the names of the people that he spoke with. And even though he formally could have ordered them to leave, he let them finish their job.

It follows from this example that the identification process is a social activity, which demands collaboration in order to decide if an object is a defect. The fact that the group did not have proper documentation was not visible from the outset. He found this out as a result of identifying something else as a defect, which was the lack of appropriate protection devices, and then through collaboration with his colleagues and with the people in question.

6 Facilitating interpretation

The situations described in the previous section do all introduce the phase of identification as a problematic task. In many cases the same situation/object is observed several times before it is identified as a defect and will be repaired, or reported in the ProData-system. The system used today does not act as a supportive tool in this phase of interpreting the surroundings and identifying defects. Instead the major field of application of ProData is as a formalized reporting tool, supporting the administrative units at SNRA-P.

Augmented reality (AR) is a collection of several techniques used to strengthen the experience of the real world [Rekimoto, Ayatsuka & Hayashi, 1998]. In this case we have an interest in simplifying the inspectors manual working tasks, we have no intention to introduce highly automated systems in their organization. The physical environment, which is their working place, could be used to tag digital information. Similar examples are implemented in much more limited settings such as office environments [Rekimoto, et al, 1998] [Ljungstrand, Redström & Holmquist, 2000]. Rekimoto uses the term 'augment-able reality', where people can dynamically create digital data and attach it to the physical context [Rekimoto, et al, 1998]. This could very well be done along the road network. The following paragraphs summarize the implications for redesign of the current system, to integrate loosely coupled methods of recalling, delegating and informing about actual conditions into the formal reporting tool.

Design for mobile use: The need to stop the vehicle in order to either communicate or report is probably the most important factor hampering these activities. Thus, designing a system that makes these activities easy to perform at the same time as being mobile could increase the number of reports and communication and thus strengthen the possibilities for articulation of the activities. The organisation would receive better knowledge of the defects and could plan their work in another way e g new forms of job sharing and job rotation.

Support for collaboration: The system must also support collaboration in a higher extent. There is a need for a stronger focus on articulation work and sharing of information as a mobile activity. Based on findings from the project following design implications are proposed when adding new features to the system.

Place-memo – Voice-memo with association to a place: We suggest a system with a looser connection between the place of the defect and the actual formal reporting. Instead the driver make a voice-memo associated with the position of the defect. When a defect is identified he push a button (perhaps on the steering wheel) coupled to the computer. A position is registered and the computer starts recording an audio-file, maybe containing something similar to what they now are writing on the post-it notes. We call this service or application a *place-memo*.

Supporting several work tasks: It has been suggested in CSCW-research that the systems should support both individual work, as well as collaboration, in order to become meaningful tools for work. This is also a problem with the ProData system that explains the way they use it. However, the place-memo could become a more integrated tool for inspection work. To fit with current practice, i.e. the articulation work, it is essential that the system should handle different forms of information, that is both situated and contingent ways of representing defects as well as the filing of data according to the formal organisational requirements. Voice-recordings have this possibility.

Supporting individual work: The system should support planning of individual work with an easy way to retrieve the place-memos. Here we suggest using software that automatically transforms speech to text. But the reminders could also be triggered automatically by for example time, route, location, etc. During the tour the reminders could be used so the inspectors could prepare a stop in time, which is especially important when the roads are crowded with vehicles.

Support easy reporting: The system should support the reporting procedure. Reporting will be saved to a better occasion than driving on the motorway. The inspector could e.g. listen through and code the messages before or after a brake.

Support for delegation: Delegation could be performed at a more suitable occasion with place-memos. It could be a support when calling a colleague. The speech to text function could also be coupled to the electronic mail for asynchronous communication.

7 Discussion and future work

In this paper we have described a study focusing on simultaneous activities, ongoing movement in combination with other working tasks. The environment, where a planned prototype should be introduced, is complex and difficult to model. A framework discussed in the beginning of the article does not cover all aspects. Kristoffersen and Ljungberg [Kristoffersen, et al, 1999A] claim the importance of looking away from transforming the desktop metaphor in mobile computing. They use three different modalities to categorize mobility, but still these categories seem to derive from stationary work. Most of them seem to view mobility and work to happen in a sequence, instead of as simultaneous activities. In the case presented, work is obviously performed simultaneous while being mobile – work in motion. The same phenomenon was observed in the study of the snow crew at Arlanda airport.

The model describing the different modalities should be revised to cover this aspect of simultaneous activities. In examples given by Kristoffersen and Ljungberg [Kristoffersen, et al, 1999A] the *travelling*-category do only affect the interaction-style. Travelling is only seen as a process of going from one place to another in a vehicle. They see the places before and after the travel as very important when conducting work. They do not imply the influence of contextual changes inside and outside the vehicle when moving along the roads.

The development work has started, where we collaborate with the Swedish National Road Administration-Production. When this work is presented we hopefully have introduced a first fully working prototype in the vehicles. After a period of evaluation a second prototype will be developed and integrated into the existing system. Main features in the second prototype will include possibilities to transmit and receive while on the move.

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