DESIGNING
INFORMATION
TECHNOLOGY
FOR EMERGENCY
RESPONSE

This thesis contributes to our understanding of information technology use in emergency response work and how information technology could be designed to provide support in emergency response work. The work domain of operative emergency response has been studied by extensive ethnographic fieldwork at several different fire and rescue services in Sweden. Prototypes have been design and used by fire crews in field experiments in order to probe for potential future use of information technology and to study its consequences.

The results presented in this thesis suggest that the design of information technology should focus on the social interactions among the response actors involved in time-critical response work. In the collective efforts of making sense in emergency response, actors use a range of information technology artifacts that produce a range of digital traces that say something about the ongoing work. Future information technology should be designed to make use of such traces of actions in order to improve the visibility of the actors and their actions in ongoing the response work.

By designing for social interactions and designing for traces of actions, new improved features of information technology could be materialized that will make emergency responders better equipped for sensemaking activities in emergency response work.

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DESIGNING INFORMATION TECHNOLOGY FOR EMERGENCY RESPONSE | JONAS LANDGREN

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Jonas Landgren | doctorial dissertation

Designing information technology for emergency response

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Abstract

This thesis contributes to our understanding of information technology use in emergency response work and how information technology could be designed to provide support in emergency response work. The work domain of operative emergency response has been studied by extensive ethnographic fieldwork at several different fire and rescue services in Sweden. Prototypes have been design and used by fire crews in field experiments in order to probe for potential future use of information technology and to study its consequences.

By using sensemaking as an analytical lens, new aspects in emergency response work have been identified that influence the design of information technology support. The results from the extensive fieldwork and the field experiments presented in this thesis suggest a new conceptualization of response work as patterns of practice *where the collective efforts of making sense is fundamental for successful response work. The conceptualization makes visible the importance of carefully embedding the use of information technology in the situated time-critical response work.*

Based on the patterns of practice, *two general design dimensions have been formed, extending our current knowledge of how information technology should be designed for emergency response work. Current information technology has primarily been designed for a formal role or specific task. The results presented in this thesis suggest that the design of information technology should focus on the* social interactions *among the response actors involved in time-critical response work. In the collective efforts of making sense in emergency response, actors use a range of information technology artifacts that produce a range of digital traces that say something about the ongoing work. Future information technology should be designed to make use of such* traces of actions *in order to improve the visibility of the actors and their actions in ongoing the response work.*

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Jonas Landgren

Content

1 Introduction

Modern society is vulnerable to disturbances or collapse of critical infrastructure caused by accidents or natural disasters. Efficient responses to such events are not only important in order to limit the consequences in a human dimension but also from environmental, economical and political dimensions.

During the last few years, disaster and emergency response has gained increased attention by IS/IT researchers. Major efforts have been made by national and local emergency authorities to design information technology that can support and improve the work on organizational levels, inter-organizational levels, national levels and even global levels in case of emergencies or crisis. Independently of the scale of an emergency, information technology use in emergency response organizations aims to provide improved ability to make competent actions in order to intervene and take control over dynamic and unfolding situation. Traditionally, attention has been primary paid to work in command centers as well as on higher-level decision making in the event of emergencies. In the last few years, information technology support has started to become an important tool also for operative emergency response work.

To a large extent, current academic research has not addressed the role of information technology in practices with time-critical characteristics as found in operative emergency response work. There are few empirical studies of operative emergency response work and there is a need to perform such studies to be able to identify general characteristics and form design implications for information technology support. Emergency response work is a time-critical work practice, where periods of relative low-intensity work are rapidly shifted into high-intensity work associated with a high degree of ambiguity. Emergency response work is therefore a valuable setting for investigating new design of information technology for time-critical work practices.

1.1 Research Aim and Question

The aim of this thesis is to understand emergency response work, inform the design of information technology use for such work and to improve time-critical emergency response work. This knowledge is of increasing importance in the ongoing efforts at local and national levels of developing the

response capabilities to everyday emergencies and large-scale disasters.

Accordingly, the research question in this thesis is: *How can information technology be designed to support emergency response work?*

1.2 Structure of thesis

This thesis is a collection of five published peer-reviewed research papers where each paper contributes to the synthesized result presented in this first part of the thesis. The first part of the thesis serves as an introduction presenting the research aim, background, theory and research approach. The following section (section 2) provides the background for the thesis by presenting emergency management, everyday response work and related research. Section 3 presents sensemaking as the theoretical ground in this study. The research approach is presented in section 4. The research contribution is presented in section 5, including a brief summary of the papers, a presentation of the prototypes used in this work, followed by the conceptualization of emergency response work patterns, and finishing with the two design dimensions *designing for social interactions* and *designing for traces of actions*. Section 6 provides the conclusion.

The second part of the thesis consists of the five papers, presented in chronological order. The papers consist of one journal paper followed by four conference papers. An earlier version of paper 1 has been awarded best PhD-student paper and paper 3 has been nominated for best conference paper. Paper 4 has been co-authored with Urban Nulden.

The five papers included are:

Landgren, J (2005). **Supporting fire crew sensemaking enroute to incidents.** International Journal of Emergency Management. Vol2, No3. Inderscience Enterprises Ltd.

An earlier version of this paper was published in: Landgren, J (2004). Fire Crew Enroute Sensemaking, In the proceedings of International Workshop on Information systems for Crisis response and management, Brussels, Belgium. (Awarded for best PhD-student paper)

Landgren, J (2005). **Shared use of information technology in emergency response work.** In the proceedings of Second International Conference on Information Systems for Crisis Response and Management (ISCRAM). Brussels, Belgium.

Landgren, J. (2006). **Making action visible in time-critical work.** In the proceedings of the Conference on Human Factors in Computing Systems (CHI2006), Montréal, Québec, Canada, ACM Press. (Nominated for best paper)

Landgren, J and Nulden, U (2007). **A study of emergency response work: Patterns of mobile Phone Interaction.** In the proceedings of the Conference on Human Factors in Computing Systems (CHI2007), San Jose, US.

Landgren, J (2007). **Investigating the tension between information technology use and emergency response Work.** In the proceedings of the European Conference on Information Systems (ECIS2007), St Gallen, Switzerland.

2 Background

To minimize the risk and consequences of accidents and disasters, modern societies have professional organizations responsible for emergency management. The organization, time-critical aspects as well as everyday response work will be described in the following subsections in order to present a comprehensive view of the key aspects of emergency management for this thesis.

2.1 Emergency Management

In order to approach the domain of emergency management, the concepts of hazards, emergencies, accidents, and disasters will be briefly defined. A hazard is a potential or existing condition that may cause harm to people, property or the environment. An emergency is a sudden and unexpected event threatening the safety of people, property or the environment and therefore requires immediate action (Cronan, 1998). Accident and disaster signal the relative scale of impact of an event along temporal, emotional and economical dimensions for a particular society. A series of unfortunate events in hazardous conditions often result in an accident that has limited impact on society but nevertheless a tragedy for the involved people. A small-scale accident during dynamic conditions always has the risk of escalating to become a disaster on a societal level.

2.1.1 Organization

Emergency management could be conceptualized as consisting of the following four interrelated functional areas; prevention, preparedness, response and mitigation, which correspond to the disaster-life cycle (Drabek & McEntire 2003). The responsibility for these functional areas spans across several community organizations but the primary organization for emergency management is the fire and rescue services (Cronan, 1998). Fire and rescue services have a distinct responsibility to prevent accidents from happening and to respond to accidents whenever they do happen. In Sweden, this responsibility is regulated by national laws. Fire and rescue services are traditionally organized according to the functional phases, prevention, preparedness, response and mitigation. In case of an emergency with the immediate need to organize a response, a temporary organization structure is formed to provide command and control (Heath, 1998). This organization is often referred to as the incident command structure (Bigley & Roberts, 2001) or the incident management system (Perry, 2003; Buck, Trainor, & Aguirre, 2006). The purpose of this organization is to rationalize and organize emergency responders while simultaneously enabling the integration of pre-planned resources into the response work (Perry, 2003). One of the often-proclaimed key benefits of such a structure is its ability to provide distinct authority and responsibility (Cronan, 1998) in time-critical situations.

The organization of emergency response work is influenced by a command and control approach due to several factors. In the 19th century, fire and rescue services were formed by civil-defense directors and personnel with a military background leading to a paramilitary organization-style as a consequence (Drabek & McEntire, 2003). Further, the command and control approach has rational qualities and is influenced by classical management theory (Britton, 1989). The approach is also favorable due to the government's role in emergency and disaster response as the one having the ultimate responsibility for the safety and the security of the citizens (Schneider, 1992).

From the perspective of disaster sociology, the command and control approach has been heavily criticized for not taking into account the emergent properties of emergencies, favoring concentration of decision-making, putting too much emphasize on hierarchical communication, a strong focus on pre-planning, and the assumption that chaos will always follow a disaster (Britton, 1989; Dynes, 1994; Neal & Phillips, 1995; Drabek & McEntire, 2003). Instead, disaster sociologists emphasize that emergency response operations should be organized based on a decentralized structure that better accommodates cooperation between professional actors as well as viewing the public as a resource (Dynes, 1994; Neal & Phillips, 1995). Further, they also advocate that an emergent behavior is beneficial to the extent that new organizational structures as part of the response work function to bridge the potential organizational gaps in a specific emergency (Britton, 1989; Drabek & McEntire, 2003).

2.1.2 Time-critical response

Response is one of four core functional areas of emergency management. In this area, emergency responders are the key personnel responsible for having the preparedness and ability to intervene instantly and rapidly in

a situation where people, property or the environment is at risk as a consequence of an accident or disaster. This means that time and temporality (Zerubavel, 1981) are critical aspects in such work. Emergency response work has specific work rhythms (Reddy & Dourish, 2002) and temporal structures (Orlikowski & Yates, 2002). Such rhythms and structures could be affected by the introduction of new technology (Shen, Yoo & Lyytinen, 2006). See paper 3 for a detailed presentation of the specific work rhythms and see paper 5 for a detailed presentation of time, temporality.

Time-critical work such as operative emergency response work is distinguished from other types of work by a set of specific characteristics (Orasanu & Connolly, 1992; Flin, 1996). First, the time-critical aspects are related to the reactive nature of this work. There is a time-pressure on the involved actors to physically intervene to the a sudden event in as short time as possible (Burke & Hendry, 1997). Second, the time-critical aspects are also related to uncertainties and ambiguities caused by incomplete information. Third, the immediate actions are dependent on team-based collective actions and are to a large extent irrevocable and irreversible. Fourth, the situation is dynamic and evolving, leading to changing and sometimes competing, goals. Fifth, the involved actors are working on different time-scales (Brehmer, 1991) depending on their role and responsibility (Fredholm, 1997).

2.2 Everyday response work

This chapter presents the work setting and work practice of firefighters. This presentation will first describe the fire crew, a description of the tasks during a workday, tools and training, and information technology support. This section ends with a description of typical emergency response work.

2.2.1 The fire crew

A fire crew consists of four to seven firefighters and one fire crew commander. The fire crew could be either part-time or full-time employed. Part-time employed fire crews have normal jobs and are on call, standby for alarms, every third or fourth week. This means that when they are on call, and they receive an alarm, they are expected within five minutes to proceed to the fire station, gear up and dispatch to the accident. In Sweden, part-time employees are common in fire and rescue services outside the larger metropolitan areas. In contrast to part-time fire crews, full time fire crews have their workplace at the fire station and when the alarm sounds in the fire station speakers, they have ninety seconds to gear-up and dispatch. A full-time fire crew is in many cases a very tight collective of people, with a long history of working together, sometimes 10 years or more. Traditionally, to fill the position after retired firefighters, new members are often recruited based on personal connections with the local sports community or among crafts workers. This process is under change due to a new educational system where firefighters are required to meet the standards of a two-year formal rescue and risk education. When people retire from the fire and rescue services, many still continue to be part of the social setting via the activities arranged by the veteran club.

2.2.2 The station

Fire stations are often located centrally in cities and characterized by the high communication tower and the five to ten garage doors for the rescue vehicles. People in general sometimes overestimate how many firefighters work at a specific fire station due to the range of garage doors of the fire station. A typical fire station has only one fire crew of 5 to 8 people on shift.

When visiting a fire station, the garage with all the rescue vehicles are often the first place that visitors will be shown to. The garage also consists of a smaller mechanical shop for minor repairs. Adjacent to the garage, large whiteboards and maps are attached to the walls presenting the district and the people on call on the specific work shift. Each firefighter has their own room during the work shift. These rooms are typically located on the second floor and the fire pole provides rapid access from the second floor to the vehicle garage. Almost all fire stations also have their own gymnasium and a well-equipped gym with weight lifting gear, bikes and treadmills.

On various places at a fire station, old-time equipment is displayed on the walls signaling a long tradition of fire and rescue work. A fire station has also a kitchen and a dining area where the fire crew eat their meals. Depending on the size of the fire station, some stations also have a pub-like socializing area, where fire crews arrange crew parties several times a year. Meetings and formal education takes place in the classroom with wall-sized whiteboards and stationary computers. The administrative personnel and the fire crew commanders have their own offices equipped with stationary computers and printers.

2.2.3 The workday

A typical day starts around the coffee table fifteen or twenty minutes prior the formal start of the work shift. This provides the opportunity for the new work shift to small-talk with the fire crew finishing their shift, about vehicle, equipment, tools and if they have had any alarms. A common question is *"well....have you had anything today?"*. The 'anything' is a reference to any alarms and the type of alarms. The response could be *"...no.... just a few automatic alarms"*.

When the workday formally starts, the fire crew meets in the vehicle garage or in the classroom for the role assignment. Following the role assignment, the fire crew commander informs the fire crew about brief organizational news, the activities planned for the specific workday. One of the key issues that is often discussed is the operating status of vehicles, tools and equipment. This discussion is commonly triggered by information from the previous work shift reports of malfunctioning equipment.

In order to have a high-level of preparedness and readiness for an alarm, vehicles and critical equipment is tested. This test is conducted after the role assignment and information activities. The test or status check of vehicles and equipment is a practical procedure where the vehicles are started, water is filled-up, the oxygen masks are checked and the ladder on the ladder engine tested by a set of maneuvers.

A typical work shift for a fire crew is organized around training, tool exercises and various types of smaller service jobs. Depending on the type of work shift, the number of planned activities varies. The day work shift includes several planned activities such as testing a particular rescue procedure, visiting an industry-property for orientation or having a school class visiting. The night work shift typically includes just a one activity such as minor service jobs on the equipment. The twenty-four hour weekend work shift includes often one major activity such as an incident exercise or a tool exercise. Independent of the type of work shift, physical exercise is always conducted during the shift, often in the fire station's sport facilities.

Even if the normal workday for the fire crew is filled with scheduled activities, everything is done with an understanding that the alarm could sound at any moment. Many firefighters express that they are constantly waiting for the next accident. This means that when the fire crew is sitting in the classroom taking part in some formal training, when the alarm sounds everything at hand is dropped and the fire crew dispatches to the accident. In the middle of a very enduring physical exercise such as football, when the alarm sounds, the fire crew is expected to be able to perform their duties on a large-scale accident. During the night shifts, when the alarm sound 03:00 in the morning, the drivers of the rescue are expected to quickly wake up and within 90 seconds be able to drive at high speed to an accident location.

As a consequence, fire crews have developed strategies to handle these swift shifts of activities. During physical exercise, which is done on every shift, extra clothes are positioned near the exit of the training facility. Many firefighters sleep in t-shirt, socks and trousers or position their shirt and trousers in order to improve a rapid transition between activities. These two examples might seem trivial but signals a mind-set that rapid transitions between activities is constantly maintained.

2.2.4 Tools and training

A rescue vehicle could be viewed as a toolbox on wheels. Each tool or set of equipment is positioned in relation to its intended use and often grouped according to type of incident. Tools and equipment for traffic accidents, such as the cutting-tools, are in one rack, equipment for chemical hazards in another, handheld power tools in a third rack and the common water-suppression equipment with nozzles and fire hoses are grouped together over several racks.

The positioning of tools and equipment is done in order to provide tool-deployment as fast as possible when arriving and working on the accident site. Over time, old tools are replaced and new are added. When new equipment is introduced, all fire crews on the fire station must first be instructed in its intended use. During such education activity, the fire crew also has the opportunity to reject a tool or set of equipment if it is collectively not understood to meet the requirements by a fire crew. Further, even if a tool or piece of equipment is added, it does not mean that the specific tool or equipment will be used or used in such way as intended. The fire crew has a form of use-mandate, which means that they decide when and how to use the tools. Obviously, for some pieces of equipment such as equipment for personal safety, the use-mandate is less evident.

The wide selection of tools and equipment also means that a significant part of the training is focused on the tool and equipment deployment. Many tools are designed to be used in a system of other tools and the

sequences of tool use need to be practiced. Tool-exercises are often done at the fire station courtyard, having all members of the fire crew practicing the various sequences. However, when it comes to fire extinguishing or practicing interior search and rescue, the fire crew often go to specialized training facilities.

2.2.5 Information technology

There is a range of information technology artifacts and systems in place to mediate communication in emergency response work.

One of the core technologies are radio communication devices. Each firefighter in emergency response work is equipped with a radio handset in order to provide communication within people in the fire crew. These radio handsets are often placed in re-chargers inside the rescue vehicles. When the fire crew mount the vehicle, the firefighters fetch a radio device and put it in the radio-pocket of their jacket. In addition to the personal radio handsets, each vehicle is also equipped with vehicle-mounted radios used during transportation. The personal radio devices are set on a group radio frequency whereas the vehicle radio typically is set on a frequency for communication between the command centre and different rescue vehicles.

The widespread use of mobile phones in society is also evident in fire and rescue services. Fire crew commanders, higher-ranking commanders and administrative personnel use mobile phones as part of their everyday work. Firefighters are typically not equipped with mobile phones. However, firefighters often carry their private mobile phone in the side-pocket of their uniform. In emergency response work, many incident commanders rely heavily on mobile phone use for communicating with the command centre. The mobile phones provide a form of privacy in contrast to the un-encrypted radio broadcasting. An indicator that mobile phones are fundamental in this work setting is that some fire crew commanders as part of emergency response have three different mobile phones; their private phone, a phone to be used in everyday administrative work, and one phone to be used in emergency response work.

In addition to personal communication devices, in the last few years GPS-navigators have become a common technology in the rescue vehicles. The navigators used in rescue vehicles provide support for route advice, visualized on a map or by turn-by-turn advice, from a given location to the accident location. These navigators are often commercial off-the-shelf products either requiring explicit address input or having automatic address location triggered by an address message form the command and control centre.

In the last few years, mobile incident support systems have gained increasing attention and interest by fire and rescue services. Mobile incident support system consists of a set of applications integrated into one system with the objective to support a range of task in the operative response work. Mobile incident command systems include applications for navigational support, access to maps, predefined response plans, property information and access to hazardous material databases. Response-plans consist of textual descriptions of the property, information about the business activities, name and phone number to contact persons, specific risks or hazard material, pre-determined entry-points to the buildings and availability of fire hydrants on the accident location. It also includes photos and/or schematic drawings of the buildings on the property.

The mobile incident support systems are designed to target the needs and use of the commander of the fire crew. These systems are installed for in-vehicle use in the front seat between the driver of the vehicle and the fire crew commander. Touch-screen, keyboard and mouse are used for the user interaction. Depending on the type of installation, the system could also be used outside the vehicle on a tablet PC or laptop. The mobile incident support system use often a combination of Mobitex/GSM/GPRS/UMTS for connection to command centre systems or back-end information systems. The Mobile Incident Support Systems are typically targeting the need for field operative commanders and the role of the incident commander.

2.2.6 Emergency response

Inevitably, emergencies do occur and the need of a rapid response by fire crews becomes crucially important in order to limit the harm to people, property and the environment. The following illustration of emergency response work is a short version of a fire alarm presented and analyzed in detail in paper 3.

The distinct sound from the fire station alarm speakers creates an immediate interruption of the current ongoing activity. The fire crew experiences a sense of awakening where the sudden alarm is forcing them to switch focus, listen to the crackling sound when the command centre operator says:

"Station B. Major Alarm. Automatic fire-alarm at
the Carl-Johan School, Admiral street seventeen."

While the voice informs about the alarm, the firemen and fire crew commander (FCC) proceed rapidly to the protective gears and rescue vehicles in the ground-floor garage. On their way to the ground-floor the fire crew speaks rapidly in short sentences clarifying the address and the driving directions to the location.

FCC: Did he say Admiral Street seventeen or seventy?

FIREMAN: Seventeen...it is on the east-end of the Admiral street.

The level of intensity is highly shaped by the 90 seconds turn-out time limit and also strongly related to the type of alarm and the time of day. The rescue vehicles leave the fire station and start the transportation towards the accident location. The fire crew commander has now assumed the role as incident commander. Radio contact is established with the command centre and confirming that they are on their way. The command centre operator (CCO) informs the incident commander about what is known about the accident and what additional resources at this point in time have been dispatched. Often, the words of the command centre operator are hard to hear by the firemen sitting in the backseat. The incident commander repeats the information to the fire crew. Suddenly the command centre operator informs:

CCO: We have received a call from the school and they say that there is a fire in a hall-way of building C...you will get backup from station C and station D with rescue and ladder units.

IC: That is acknowledged...did you say building C?

CCO: That is correct, over.

The time period of transportation provides the fire crew with a few minutes for preparation of what will face them upon arrival. When arriving to the accident site, visual impressions and the way civilians act on the location influence the intensity of the intervention actions. Visual signs of emergency, such as thick black smoke-clouds, flames out of the window of a building or a severely crashed vehicle are triggering factors.

Based on the snap-shot visual impression of the situation a verbal report, a window report, is provided by the fire crew commander, in the role of incident commander, by radio to the command centre operator. This report is very brief and the work intensity does not permit any discussions or follow-up questions, just a short confirmation from the command centre that the report has been understood.

IC: (In vehicle F511): G400... F511 arrived... we have a fire and there is heavy smoke from the hallway... I report back later.

CCO: F511 that is acknowledged.

This report is the first verbal formulation to the command centre that explicitly captures what the situation is all about, based on a professional responders understanding. The window report is communicated using the radio allowing other fire crews enroute the accident location to take part of the information. There can be significant differences between what a non-professional has told in the 112-SOS call and what the commander reports upon arrival.

When the fire crew dismounts the vehicles, the incident commander starts a situation assessment and the firemen begin to deploy equipment according to a pre-planned routine that corresponds to the situation at hand. The situation assessment has the goal of providing fundamental understanding of the emergency in order to determine how to take control of the situation and minimizing its consequences. During the situation assessment, the incident commander uses the fire crew open radio channel to inform about the situation that could require changes of the intervention tactics.

While the incident commander is conducting the situation assessment the fire crew begins the physical intervention based on a set of coordinated activities, where each activity contributes to the progression of the intervention. The pace in this work is significant. The driver of the vehicle man the pump, the breathing apparatus team (BA-team) starts to lay fire hose and locate how to get close to the fire. In case of locked doors they apply the "break-in" kit to get access. The action of breaking-in is reported back, over radio, to the commander. When the BA-team is ready to move into the hallway, they call over the radio to the pump operator who set pressure on the fire hoses. The BA-team's eagerness to start fire suppression as fast as

possible puts pressure on the pump operator to have finished the appropriate actions to provide water. During these activities there is an intense communication over the fire crew's open radio channel.

After additional minutes, a status report is communicated to the command centre allowing the operators to update and prepare the arrival of additional units. Status reports are communicated over the radio or a mobile phone to the command centre. The following excerpt is from a mobile phone conversation where the incident commander is providing a status report:

> **IC:** We have a fire here in the hall-way, we have initiated extinguishing. There are some cardboards and rubbish on fire and heavy smoke. I would like to have station C prepared to initiate search and rescue.
>
> **CCO:** That is understood.

The command centre operator calls over the open radio channel to inform the fire crew in the vehicles enroute about the situation and the task that they should prepare for. Meanwhile a higher-ranking commander has arrived as part of the build up of resources and need of additional command levels. The higher ranking commander takes over the role as incident commander after a brief situation update with the commander from station B.

The incident commander and the fire crew commanders work on different time scales. The fire crew commanders work close with their fire crews and are directly involved in the physical work whereas the incident commander provides distance, both physically and mentally, in relation to the emergency, and is focusing on keeping multiple alternatives open for any sudden changes of the progression of the response operation.

The unit from station C assigned to search and rescue has found additional floor levels that are filled with smoke. The incident commander immediately contacts the command centre over radio:

> **IC:** We have found additional smoke on level three and four. When will station D be here, over.
>
> **CCO:** Wait a moment.
>
> **CCO:** They are arriving right now.
>
> **IC:** Good, I estimate that we will be here for the next hour, it will take some time to ventilate this building.
>
> **CCO:** That is confirmed.

Eventually the building is ventilated and the search and rescue efforts work finishes. The work of the fire and rescue services is coming to an end on the incident location. Fire crews start to demobilize as soon as the work at the incident location comes near completion. The incident commander informs the command centre of the incident termination.

2.3 Related Research

Information technology for emergency response management is often designed based on influences from a command and control perspective. That perspective puts strong focus on concepts such as decision-makers, hierarchical organization of actors, vertical unidirectional decisions and information flows. These concepts have resulted in assumptions that effective information processing could produce digital representations for a common operational picture. Such representations would ensure that necessary and vital information reaches the appropriate decision-makers to make correct decisions, and from a holistic perspective give strategic direction to emergency responders (Jungert, Hallberg & Hunstad, 2006). Further, a study of firefighters' work on the accident ground suggested that radio-communication could be improved by designing radio-communication features that address the hierarchical structure of emergency response work level (Camp, Hudson, Keldorph, Lewis & Mynatt, 2000). The concept of audio-horizon would improve radio communication between individuals on different command levels by excluding communication from individuals that are not vertically linked to the specific level (Camp, et al, 2000).

However, there are several studies of command and control settings that open for a deeper understanding. As will be shown below, studies of command room settings and emergency responder work suggest a complex work practice where the situated use of information technology contrasts to the normative ideas of command and control. Studies of control-room operators and emergency dispatchers outline that decisions are co-constructed inbetween the operators as a result of the awareness of the capacity and workload of the work group (Heath & Luff, 1992; Normark,

2002; Pettersson, Randall, & Helgesson, 2002). Such awareness has shown to be provided by such simple means as over-hearing of radio-communication and the role of gestures for the cooperative work in control-room settings (Heath & Luff, 1992). Design implications for information technology to support those aspects of the work-setting call for ambient displays to unobtrusively visualize the workload (Pettersson, 2004).

The continuous improvement in the capability of mobile technologies and wireless infrastructure has dramatically changed how the mobile and distributed work of emergency response could be supported (Stephenson & Anderson, 1997). Now, when network connectivity for mobile and distributed actors is less difficult, the attention has been shifted to investigating and formulating design principles and specifications on information systems for emergency response management (Turoff, 2002; Turoff, Chumer, Van de Walle & Yao, 2004; Yuan & Detlor, 2005). In such systems, aiming to improve communication among all levels of emergency actors, a secure and redundant infrastructure (Hale, 1997; Chen, Sharman, Rao & Upadhyaya, 2005) becomes increasingly important in order to provide integration between mobile and centralized information systems (Meissner, Luckenbach, Risse, Kirste & Kirchner, 2002; Andersson & Lindgren, 2005).

The improvements of mobile technology capability have initiated a range of studies focusing on how information technology is used by field operative personnel such as police officers, firefighters and medical personnel. Considerable attention has been focused on the information technology artifacts in use and the design of such artifacts.

Studies of the use of information technology in field-operative emergency response settings have shown aspects of situated use that to some extent stands in contrast to the more normative view of how information systems should be designed and used. A study of the introduction of mobile phones in police work (Manning, 1996) has shown how mobile phones alter teamwork opportunities and tighten some relationships between colleagues while loosening relationship to others. Studies of police patrol work has showed that information technology provides a tension in the relationship between police patrols and the dispatcher, regarding police patrols' entrepreneurial perspective and the dispatchers' incident driven perspective (Nulden, 2003a; 2003b). A study of police work has illustrated the problem of introducing additional handheld communication devices to police patrols causing problems of *ready-at-hand* and *in-the-pocket* in safety-critical situations (Pica & Sorensen, 2005). Results from an evaluation of mobile, in-vehicle information technology for police officers illustrates the complexity of introducing information technology that improves collaboration between dispatchers and police officers, while at the same time conforms to the contextual demands of the field operative. The lack of focus on the actual users during the development resulted in a system that was difficult to use and therefore impaired the users' work safety (Marcus & Gasperini, 2006).

In the work domain of medical emergency response, design-oriented studies have explored how information technology could improve the work by focusing on the victim as the boundary object (Kristensen, Kyng & Palen, 2006). Prototypes were designed targeting the challenge of providing patient identification and dynamic situational overview delivered to expertise medical centers to provide improved collaboration with the field personnel (Kyng, Nielsen & Kristensen, 2006).

Firefighting as collaborative work has been studied from a commander perspective showing how accountability of the personnel's status and situation assessment are key issues in emergency response work (Jiang, Hong, Takayama & Landay, 2004). That study resulted in design ideas using mock-ups of wall-size displays to be used for visualizing available location information and the position of personnel involved in the response work. Further, pervasive technology has been designed to further explore how sensors and peer-to-peer networks could improve communication reliability and awareness of the ongoing actions (Jiang, Chen, Hong, Wang, Takayama & Landay, 2004). These studies with their specific focus on firefighters' work on the accident location present innovative suggestions on how information technology could improve emergency response work.

However, there are few studies that evaluate the design or the implications of such design in the intended work setting. A different approach was taken in a study of information technology use as part of disaster response, where the researchers brought their technology into the early disaster relief work following hurricane Katrina. In that study, the objective was to support the work by using a collaborative peer-to-peer application on the relief personnel's laptop computers. The result from this study shows how coalitions were formed on an ad-hoc basis and how mobile phones were a key technology to form these groups (Farnham, Pedersen & Kirkpatrick, 2006).

The above studies of emergency responder work and the use of information technology have uncovered how situated aspects of emergency response work present challenges when designing information technology to provide improved support for collaboration between the distributed actors. Research on emergency response work suggests that this type of work has distinctive characteristics that need to be carefully addressed when designing information technology to support such work. In contrast to the above studies where the focus have been put on describing the impact of information technology in time-critical work practices or improving task specific activities, this thesis focus on how information technology could be designed to support the underlying and always present activity of meaning construction. This thesis contributes to prior research by exploring how meaning construction in terms of sensemaking (Weick, 1979; 1995) provides a partially new perspective that uncovers new design dimensions for the application domain of emergency response.

3 Sensemaking

In the beginning of my research, the dominant model to understand what people do in their everyday work, was in terms of distributed decision making (Brehmer, 1998). This was especially true for how I initially tried to understand the work by emergency responders. However, after the first few days of fieldwork and after a set of observations of incident response work, I started to doubt. I could not see many decisions during emergency response work. Obviously, people did in retrospect talk about what they did during the response work in terms of decisions, but this was not to any extent visible for me during the response work.

Over time I started to look for other theories. Naturalistic decision-making (Klein, Calderwood & Clinton-Cirocco, 1988; Klein, 1997) and the single option decision strategy (Klein, 1993) seemed initially as suitable theoretical framework and I made a few attempts to apply their models on my collected field data. After a while and in discussions with my colleagues an alternative perspective came to dominate my future work, namely Karl Weick´s sensemaking theory (Weick, 1979; 1995). The shift to sensemaking was partially based on the observations from one small-scale accident clearly illustrating a breakdown of fire crew sensemaking. Now in retrospect I would assign the analysis of that episode as the moment in time when sensemaking theory became the theory for my work. The shift to sensemaking theory should not be seen as an attempt of fitting the world to a theory or vice versa but more as an effort of finding powerful theoretical tools to explore a specific phenomena.

Sensemaking (Weick, 1979; 1995) has been used as an analytical lens with which to investigate and understand people's activities in time-critical work. This means that sensemaking theory has provided perspectives and concepts that have been used as analytical tools to improve my understanding of important aspects of emergency response work. Sensemaking theory has been used in a range of studies of organizations involved in disastrous events (cf. Weick, 1988; 1990; 1993; 2001; Snook, 2000; Kayes, 2004).

Further, sensemaking theory has also been used to study IT in organizations and particularly IT-adoption (cf. Orlikowski & Gash, 1994; Henfridsson, 1999). In this thesis, the objective is not to focus on how people make sense of IT, but to focus on how people could make sense using IT.

Few studies have adopted sensemaking theory in order to design IT that improves sensemaking activities.

Sensemaking is both an individual and a collective process where *"reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs."* (Weick, 1995). This means that in contrast to decision making where the key question is *what shall we do?*, in sensemaking the key question is: *what is going on?* At the heart of sensemaking is the lack of fit between what is expected and what is encountered (Weick & Meader, 1992). A fundamental aspect in sensemaking is to understand that a person or a collective's experiences of a situation are progressively clarified, and that this clarification often works in reverse (Weick, 1995). In order for people to make sense, they must act, since, from a sensemaking perspective, it is understood that action precedes understanding. People actively interact to create meaning by the enlargement of small cues. The social context in which sense making takes place affects what cues will be extracted. Further, the social context also affects how the extracted cues are interpreted as well as the revision of those interpretations based on the following actions and their consequences.

The making sense is oriented towards the plausible rather than the accurate due to the time criticality. There are occasions where sensemaking is especially visible. Such occasions are triggered by ambiguity or surprise, which means that people's expectations conflict with what is experienced. More information would here not reduce ambiguity but rather increase the information load and sense of turbulence (Weick, 1995). An ambiguous situation means a situation open for multiple interpretations. In order for people to make sense in situations characterized by ambiguity they need to bring order to an overwhelming flow of experience. They do so by extracting pieces out from their stream of experiences to establish a stable environment that they can inspect and assign meaning to. When people experience ambiguity they start to engage in a set of sensemaking activities (Weick & Meader, 1992). They start to interact with other people to see what others see and negotiate a mutually acceptable version of the situation. Further, people use multiple sources of insight for comparison and they make effort to relate the ongoing situation to previous similar experiences. These activities contribute to the construction of meaning in a complex ongoing process.

In an emergency response perspective, this means that when professional actors intervene to an emergency they also *"simultaneously generate the raw material that is used for sensemaking and this affects the unfolding of the crisis itself"* (Weick, 1988, p. 305). Their actions affect the emergency and the emergency affects their future actions. On the basis of this line of argumentation, the term enactment is powerful in explaining the creation of a stable environment; *"when people act, they bring events and structures in to existence and set them in motion"* (Weick, 1988, p. 306). Enactment is understood as a social process of *"material and symbolic record of action"* (Smircich & Stubbart, 1985, p.726). The result of this process is an enacted environment consisting of real objects such as toxic material, risks, people, cargo wagons and valves. These objects are real but their meaning and significance are subject to multiple interpretations (Weick, 1988). The capacity in terms of the number of actors and the competence of those actors available to act and interpret are crucial variables. However, the acting and interpreting is not just an individual process but collective processes (Weick, 1995) which means that successful interaction between people in equivocal situations enable them to see more ways where they can intervene to decrease the escalation of the crisis. The organization and the environment are enacted through the social interaction between the key organizational actors (Smircich & Stubbart, 1985). This means that organization emerges through sensemaking, and not that sensemaking is a product of organization (Weick, Sutcliffe & Obstfeld, 2005).

4 Research approach

The research presented in this thesis is based on an interest in investigating time-critical work practice and to study the use of technology in such practice. The research has been inspired by the field of computer-supported cooperative work with its strong focus on social interactions and the use of ethnographic fieldwork to study and analyze work practices. Further, this research is conducted with an ambition to contribute to IT-based organizational change and a subsequent improvement of emergency response work. The use of experimentation in field-settings has been inspired from the field of human-computer interaction. Therefore, the research approach consists of a combination of ethnographically inspired fieldwork and field-experiments with prototypes as probes to study future work practice.

4.1 Ethnography

Ethnography with its roots in anthropology has experienced a significant renewal and growth over the last decades in a variety of knowledge domains (Wacquant, 2003) and in system design in the field of Information Systems research (Harvey & Myers, 1995). On a broad level, ethnography can be defined as "the art and science of describing a group or culture" (Fetterman, 1998). Ethnography involves the study of people as part of their everyday activities (Emerson, Fretz & Shaw, 1995). In this respect, ethnography is an appropriate method in order to study people in time-critical work and fits well with the methods adopted when investigating sensemaking (Weick, 1995) and the methods suggested from the field of disaster research (Phillips, 2002). By adopting an ethnographic approach (Hammersley & Atkinson, 1995), I have had the opportunity to learn about emergency response work and the firefighters' social setting by making participant observations, listening and asking questions. By spending a considerable amount of time in this setting, I have been able to gain acceptance to make observations and video-recording in emergency response work, listen to and audio-record the professional actors' verbal communications in critical situations, listen to how people in retrospect talk about emergencies, and ask questions related to my observations in their social setting. The outcome of these activities has been a deep knowledge about emergency response work and insights in what firefighters experience as meaningful (Emerson et al, 1995) and important in their work.

The objective of using ethnography in my work was to reveal aspects of that work setting that most people are unaware of or unfamiliar with (Snow, Morrill & Andersson, 2003), and bring social and organizational contexts (Harvey & Myers, 1995) into account when exploring information technology design for emergency response work.

Ethnographic research is an in-depth or intensive research method that is time-consuming (Myers, 1999), which is also true for my work, which covers over 1000 hours of fieldwork. However, these hours consist of shorter periods of fieldwork visits distributed over four and half years, allowing me to pull back (Fetterman, 1998), make sense and reflect upon the observations.

Ethnography has been widely used to study information systems in organizations (Hughes, Randall & Shapiro, 1992; Orlikowski, 1992). The use of ethnography to study the use of information technology is highly influenced by the seminal work on human-machine communication (Suchman, 1987) and studies of office conversations (Wynn, 1991). Ethnography in systems design may serve the following purposes; to study information technology use (Heath & Luff, 1992), to inform the design and redesign of information technology (Hughes, King, Rodden & Andersson, 1995), and to evaluate a design (Twidale, Randall & Bentley, 1994). In my work I have used ethnography to study the work setting and derive design implications that could inform the design of information technology. The research papers in this thesis; paper 1, 3 and 4 are examples of using ethnography to inform design. Using ethnography for evaluation purposes such as in field experiments as presented in the research papers 2 and 5 are examples of such approach.

However, using ethnography in systems design is not uncontested. A commonly expressed critique argues that ethnography in many cases is used merely for requirements capturing and misses the analytical perspective. This reduces ethnographic texts to impressionistic accounts of what people did (Anderson, 1994; Forsythe, 1999) and to a large extent misses how people do what they do (Button, 2000). This problem does not stem from ethnography itself but from the various ways ethnography is adopted. In my research I have adopted sensemaking as a primary theory for understanding emergency response work, and specifically used sensemaking as an analytical lens to analyze field data.

By applying key concepts from sensemaking theory, I have explored how people interact in an emergency response work practice, and made

visible aspects of that practice that is important when designing information technology to support such work. This means that the analytical perspective in my work has been the construction of meaning in time-critical work and how time-criticality causes contextual challenges that a designer of information technology should address. The descriptive accounts have made visible emergency response work practice for system designers focusing on how information technology could support meaning construction.

Design implications from ethnographic research are not necessarily exhaustive but provide implications for a possible design that needs to be evaluated (Hughes, Randall & Shapiro, 1992). The descriptive accounts in combination with design implications from my research should not necessarily be viewed as guidelines for one possible design but as insights in a variety of possible designs. In this sense, this thesis provides a few insights in how information technology could support and innovate emergency response work.

4.2 Data collection techniques

A range of different data collection techniques have been used as part of my work, including participant observation, interviewing, video and audio recording and document analysis. All these techniques fit well in the tradition of ethnography.

In emergency response situations participant observations (Hammersley & Atkinson, 1995) have been used as the primary technique to get a personal and hands-on experience of the dynamics of emergency response work. Emergency response work means that a fire crew becomes distributed across the location making it hard to study all of them at the same time. Therefore, the focus for my observations has been to follow the field commander, assuming the role as incident commander. The choice has been to study the key actor and the communication and interactions associated to that person and the mediating technology. The observations have been documented as field notes in a paper notebook and later transcribed and further expanded.

On several incidents, video material have been recorded using a handheld camera as part of the ethnographic fieldwork (Pink, 2002). The video recordings have also been used to capture sequences of interactions and communication for detailed interaction analysis (Heath & Hindmarsh, 2002). For the same reason verbal communication was recorded using a digital recorder. Verbal communication includes radio-talk, mobile phone communication as well as face-to-face discussions. Episodes of this large audio material were later transcribed.

Interviews have been conducted after larger incidents in order to capture, in retrospect, key events of the incident from the perspective of the emergency responders. The interviews were semi-structured (Patton, 1990) and conducted with groups as well as with individuals. All interviews were made at the rescue services during the normal work shifts. The purpose of these interviews has been to complement the participant observations and to collect data from the perspective of actors not covered by the observations.

In addition to the above mentioned data collection, formal and informal documentation (Hammersley & Atkinson, 1995) produced as part of the emergency response work has also been collected. The documentation consists of the rescue services paper-notes and computerized command logs from the command post at the accident location and also logs from the dispatch system at the command centre, and logs from incident management system.

4.3 Exploring emergency response work

This thesis builds on an extensive field study initiated in 2002 including over 1000 hours of fieldwork investigating the work of emergency responders. The purpose of the ethnographic study has been to study emergency response work to inform design of information technology to support such work.

The ethnographic fieldwork has largely been conducted at the rescue services in Göteborg. However, shorter periods of fieldwork have also been done at the rescue services in Stockholm, Lund, Luleå, Södertörn, Vilhelmina, and Munkedal. The selection of rescue services covers both metropolitan areas and less populated areas, as well as smaller and larger rescue services organizations. In addition to this, two minor field visits were also conducted to Tilburg Fire Services in the Netherlands and San Francisco Fire department in the US. The common denominator across all the different rescue services is the size and structure of the fire crew. The size of the studied fire crews consisted of one fire crew commander with a team of 5 to 7 firefighters.

The unit of analysis in this work has been the fire crew and the fire crew commander in emergency response work with a specific focus on the early phases of response work from dispatch, arrival to the accident location and initial response work. However, emergencies are not scheduled or known in advance, which means that a significant part of the data collected during the fieldwork also includes non-emergency activities. Following fire crews and field commanders as part of their everyday work, has resulted in a deep understanding of the work setting, the work practice and how the non-emergency and emergency response activities are interrelated. Further, I have also studied higher ranking field commanders in more complex response work giving me the opportunity to get insights and knowledge about coordination aspects between field operative work and the command centre work. Having said this, one should not forget that the focus of my research is on the field operative emergency response work.

The studying of emergency responders has been accomplished by following fire crews and field commanders during their normal work shifts which include, 10 hour dayshifts, 14 hours nightshifts and the 24 hour weekend shifts. During these shifts, I used the same type of uniform and protective clothing as the fire crew in order to blend in as well as for safety reasons. I have participated in the everyday work of emergency responders including both non-emergency work and emergency response. Non-emergency work includes activities such as training, meetings, education and service tasks. Emergency response work covered in this thesis ranges from small routine incidents such as false alarms (Paper 1), minor fires and traffic accidents to larger incidents such as house fires, school fires (Paper 3), and chemical incidents (Paper 4).

4.4 Exploring technology use in field experiments

In order to further investigate the role of information technology in emergency response work a series of prototypes have been designed and used in field experiments. During the work with this thesis, three different prototypes have been developed, in cooperation with students from the mobile service master program at the IT-university in Göteborg. The prototypes have had a limited set of functionality targeting specific issues for our explorations of a future work practice. The purpose of the prototypes was to further explore key aspects of the work practice, identified in the field data. These aspects have been transformed into implications for design and also partially implemented in the prototypes.

The fieldwork provided valuable insights in understanding the complexity of the work practice and identifying what aspects are fundamental and important. Based on the analysis of the field data, a set of design implications were derived. These design implications, target specific dimensions of the work practice where information technology could improve emergency response work. The functionality in each prototype manifests a subset of these design implications. The field experiments served the purpose of exploring the design of each prototype in the intended use context. The objective was not to verify the design but to use the design as trigger for further exploration of the use of information technology in emergency response work and to investigate the impact of such technology on the work practice.

Evaluative ethnography (Hughes et al, 1992) has been outlined as one form of ethnographic inquiry when the focus is on evaluating and validating a new design in a specific work setting and in as real situations as possible (Twidale et al, 1994). In the field experiments, evaluative ethnography has been the method of inquiry, but by using the prototypes as *triggering artifacts* (Mogensen & Trigg, 1992), the unit of analysis was shifted from the designed artifact itself (i.e. the prototype) to the work practice and possible improvements.

Triggering artifacts, originating from participatory design (Mogensen & Trigg, 1992; Blomberg et al, 1993), are used to trigger the analysis of current work practice for the purpose of change (Crabtree, 2003). The artifact is used to trigger a reaction that will uncover important aspects of the work practice in relation to certain type of technology or functionality.

4.5 Analysis

The collected data has been analyzed along the dimensions of relationships, response work and artefact. Key unit of actors have been identified with a description of the characteristics of their relationships. Over time along with the continuation of the field work, this understanding of the actors and how their relationships function has been progressively clarified. The artifact dimension has been used to focus the analysis how the emergency responders talk about their core artifacts categorized along physical tools, equipment and information technology. I have identified characteristics that constitute a *good* tool by mapping how tools and equipment are used

in emergency response work and how fire fighters talk about their tools.

Emergency response work has been analyzed according to the following procedure. Observations during response work have been documented as field notes and after each full-day of data collection transcribed and expanded into field records. These field records have been analyzed by repeatedly reading the records several times in order to identify critical episodes. Such episodes could be interactions between key actors as well as unfolding ambiguous events. In such episodes, specific attention has been paid to the type of information exchanged and the technology used in such interactions. Key episodes have been time-stamped and tagged with the associated actor and location.

Audio recordings have been analyzed by repeated listening, not only to what is said which is found in the transcripts, but also to how certain things are said, by whom to whom. Video recordings have in a similar way been analyzed by repeated viewing. The analysis of audio and video has been focused on sequences of face-to-face interactions as well as sequences of document exchanges and the use of communication devices. Extracted sequences have been time-stamped and tagged with the associated actor and location.

Formal documentation, such as incident reports and command logs, as well as informal documentation such as paper notes, lists of phone numbers, have been collected and compiled into a document log tagged with actor, time and location.

The analysis has continued by aligning the field records, audio sequences, video sequences and document logs to a general incident time-line. The time-line analysis started with the field records being analyzed and compared to audio, video and document data for each moment along the time-scale. This procedure has been repeated for each type of collected field data in an iterative process. This process has resulted in a rich set of descriptions of actors, interactions and critical events. In a few occasions (see paper 4), the incident time-line with associated data has been presented to a subset of the involved actors in retrospective interviews about the specific incident. The analysis has resulted in a set of critical issues in response work (paper 1), large-scale work rhythms (paper 3) and interaction patterns (paper 4).

Data from field experiments has been analyzed according to the following procedure.

The transcribed field notes in the form of extended field records and video material has been compared to my prior ethnographic material in order to determine the potential difference between data from exercise alarms and real emergencies. Sequences from the video recording have been selected and examined in order to get a detailed view how the prototypes were used in the social interactions. The video data has been analyzed by mapping video sequences from the field experiments to the corresponding phase in the work patterns. Each sequence was then analyzed to explore the order of how specific features of the prototypes were used. Finally the sequences were analyzed by examining how the prototypes formed the conversation among the fire crew in relation to the specific phase in the work structure. Data from follow-up workshops has been analyzed by organizing the data into a set of themes addressing specific concerns expressed by the participants regarding the prototypes they had used. These themes were then examined against the video analysis of the prototype use in order to examine a particular interaction concern. The analysis process has resulted in a set of issues (see paper 2 and 5) that should be accounted for when designing information technology for emergency response work.

5 Research contributions

The results and contributions of my research will be presented in this section including a very brief summary of the papers, a presentation of the prototypes used in this work, followed by the conceptualization of emergency response work as patterns of practice, and finishing with the two design dimensions designing for social interactions and designing for traces of actions.

5.1 The papers

The five research papers included in this thesis are briefly presented in this section. The table below provides the chronological order of these papers along with each papers primary characteristics and relation to the accumulated time of the extensive fieldwork.

Year	Paper	Type	Acc. hours of fieldwork
2005	**Paper 1** Supporting fire crew sensemaking enroute to incidents.	• Ethnography • Design implications	700 hours
2005	**Paper 2** Shared use of information technology in emergency response work	• Field experiment	800 hours
2006	**Paper 3** Making action visible in time-critical work	• Ethnography • Design implications	800 hours
2007	**Paper 4** A study of emergency response work: Patterns of mobile phone interaction	• Ethnography • Design implications	1000 hours
2007	**Paper 5** Investigating the tension between information technology use and emergency response work	• Field experiment	1000 hours

Table: Chronological order of the research papers

Paper 1 – Supporting fire crew sensemaking enroute to incidents

Landgren, J (2005). **Supporting fire crew sensemaking enroute to incidents.** International Journal of Emergency Management. Vol 2, No 3. Inderscience Enterprises Ltd.

This paper presents data from a single small-scale emergency as part of an extensive ethnographical field study. A detailed analysis of sensemaking in a fire crew enroute a small-scale emergency is outlined. Sensemaking theory is applied as an analytical lens, aiming to explain the communication between the command centre operator and the fire crew in terms of sensemaking. Further, implications for the design of information technology use for supporting fire crew sensemaking enroute to incidents.

Paper 2 – Shared use of information technology in emergency response work

Landgren, J (2005). **Shared use of information technology in emergency response work.** In proceedings of the Second International Conference on Information Systems for Crisis Response and Management (ISCRAM) 18-20th April. Brussels, Belgium

This paper presents results from a field experiment of IT-use in emergency response work of a fire crew. A prototype has been developed to probe for instances of sensemaking supported by IT-use in such work. The findings have been analyzed in relation to research on design of emergency management information systems and sensemaking theory. Key findings from the field experiment suggest that there is a potential conflict between the role-based emergency

management information systems and the shared use of information technology of first responders.

Paper 3 – Making action visible in time-critical work

Landgren, J. (2006). **Making action visible in time-critical work.** Conference on Human Factors in Computing Systems (CHI2006) , Montréal, Québec, Canada, ACM Press. (Nominated for best paper)

This paper presents descriptive accounts from an ethnographic study of time-critical work in the domain of emergency response and the operative work of fire crews. The verbal communication as part of such work creates difficulties in providing accountability of the fire crew's actions. The

concept of work rhythms and temporal structures is used as an analytical framework. Design implications are presented suggesting that verbal communication should be made persistent, visible and accessible in order to support accountability. These design implications are discussed in relation to the fire crew's work practice.

Paper 4 – A study of emergency response work: Patterns of mobile phone interaction

Landgren, J and Nulden, U (2007). **A study of emergency response work: Patterns of mobile Phone Interaction.** CHI2007, San Jose, US.

This paper presents descriptive accounts of time-critical organizing in the domain of emergency response. Patterns of mobile phone interaction in such work is analyzed showing how the dyadic exchange of mobile phone numbers between the actors plays an important role in the social interactions in the organizing and sensemaking of the emergency. Enacted sensemaking is used as an analytical framework. Implications for design of emergency response information technology are outlined and discussed.

Paper 5 – Investigating the tension between information technology use and emergency response work

Landgren, J (2007). **Investigating the tension between information technology use and emergency response work.** ECIS2007, St Gallen, Switzerland.

This paper presents results from an investigation of information technology use and time-critical work response work. A major challenge of mobile information technology use in time-critical work settings is to balance the temporal impact on the work practice caused by the technology. Results from a field experiment indicate how technology could be designed to comply with temporal aspects in a work practice characterized by rigid temporal structures. This paper contributes to previous research on the inter-related relationship between the temporal aspects of the work practice and the use of information technology.

5.2 Prototypes in action

This section presents the prototypes used in my research. These prototypes should be seen as both important instruments for conducting this research as well as independent results.

In a series of field experiments in 2004 and 2006, three prototypes were put in action as triggering artifacts. The field experiments were conducted as part of the participating fire crew's normal work-shift. The field experiments served different purposes and where conducted with prototypes ranging from low-fidelity standalone prototypes to low-fidelity networked prototypes. All prototypes were used on Tablet PCs due to their mobility and relatively large screens suitable for collective interaction.

The purpose of the 2004 experiments was to explore how information technology could support collective sensemaking among the fire crew (Paper 3). The series of experiments in 2006 aimed to investigate how information technology could support sensemaking in a context also including external actors on the accident site (Paper 5). The three prototypes are Resqpad, Rescuelab and Incidentweb.

YEAR	2004	2004	2005	2006
CITY	Göteborg	Göteborg	Göteborg	Göteborg
TYPE OF LOCATION	Factory	Factory	Railroad facility	Factory
PROTOTYPE	**ResqPad** Standalone application	**RescueLab** Standalone application	**IncidentWeb** Network enabled application	**IncidentWeb** Network enabled application
PAPER	Paper 2 – Shared use of information technology in emergency response work.		Paper 5 – Investigating the tension between information technology use and emergency response work.	

Table: Field experiments

5.2.1 ResqPad

The Resqpad-prototype was designed to explore how firefighters could access location-specific information to form their actions as part of the response work. Resqpad was developed by a group of master's students part of the research project. The prototype consisted of an application running on a Tablet PC. One of the key functionalities was the ability to draw simple sketches on top of underlying geographical information such as maps, aerial photos and building blueprint of a particular location. The

key feature of the prototype was the functionality to distribute these sketches to other users with the same application. The information about a particular location was stored locally in the application and did not allow for multiple locations. Resqpad was used in a field experiment with the objective to explore the use and effects of the sketch functionality. The field experiment showed that simple sketches superimposed on top of location information provided support for the incident commanders situation update. The material mediated by the prototype improved the capacity to make sense of the location in face-to-face interaction. The following excerpt illustrates briefly how the incident commander (IC) updates the other firefighters (FF) on a fictitious situation.

ACTOR	CONVERSATION	GESTURE	PICTURE
IC:	So you are from the Gårda fire crew?		
FF:	That is correct.		
IC:	We have a fire in the eastern side of the building.	Pointing on the map overview.	A
FF:	Hmm.		
IC:	The access road is here, so we are now standing on the field over here.		
FF:	Yes.		
IC:	I want you to approach from the northern side to secure these storage rooms.	Switching to blue-print.	B
FF:	Yes.		
IC:	Our guys have entered the building from this side and the fire is localized here.		
FF:	Alright.		
IC:	Your task is to approach from this northern side.		
FF:	Good, we will get started, and which channel should we use?		
IC:	85B.		
FF:	Okay.		

Table: Communication excerpt of RescuePad use

Picture A

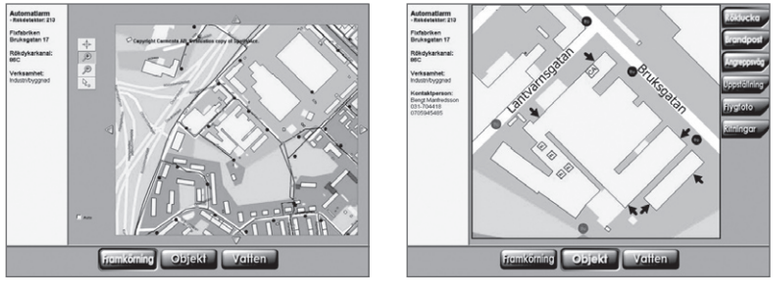
Picture B

The results from the field experiment provided valuable insights regarding the use of information technology in social interactions as part of the response work. Providing improved support for social interactions was further explored in RescueLab.

5.2.2 RescueLab

The RescueLab-prototype was developed as part of a project tightly involving a fire crew in the design work. One of the key issues was to investigate if information technology could support the fire crew's sensemaking activities in response work.

In this project, two master's students developed the RescueLab-prototype, which to some extent had a functionality similar to that of Resqpad, with more details regarding location specific information. The project resulted in a standalone application with features allowing the users to change the level of details in the location specific information such as maps, blueprints, textual information, aerial photos and risk information.



Screenshots of the RescueLab user interface

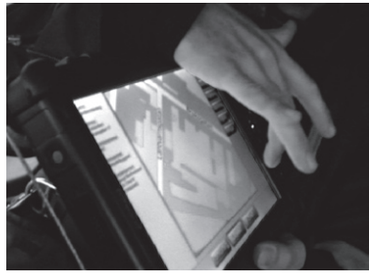
The three buttons on the bottom-side of the interface provide navigational access to information targeting the different phases during response work. The buttons on the right-hand side provided support for manipulating the level of details of the specific information.

The prototype was used in a field experiment at an industrial facility. The following excerpt from the field experiment illustrates how the fire crew made sense of the incident location at the factory premises.

IC = Incident commander, DRIVER = driver of the vehicle,
FM = Fire Crew Foreman

ACTOR	CONVERSATION	GESTURE	PICTURE
IC:	If one looks from the Landstrikestreet, then it should be somewhere here .	Pointing on the screen.	
IC:	Take it [the tablet pc].		
DRIVER:	It's the back of the factory you see from up there.	The IC hands over the device to the senior fire fighter in the backseat.	
IC:	Yes, no other side of the factory is visible to him [the alarm-caller].		A
FM:	There is, up there...is the Landstrikestreet.	Leaning forward showing the screen.	B
IC:	Uhu huh.	The IC turns round and looks at the screen.	
FM:	Hmmm...at the back...		

Table: Communication excerpt of RescueLab use



Picture A

Picture B

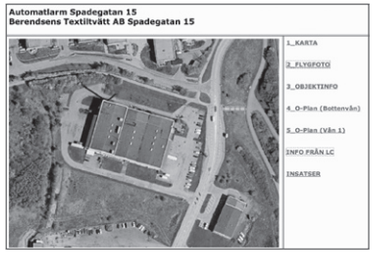
The primary result from the field experiment show how the location maps provide material for sensemaking by improving the ability of using reference points to determine the plausible location of the incident location. The location maps provide cues to the people in the vehicle about the factory surroundings. Together with their prior experiences this forms the commitment of where on the premises to proceed. For a full description of the field experiment and the results see paper 2.

5.2.3 Incident Web

In contrast to the previous prototypes, being stand-alone applications, the objective here was to design a platform for mobile information access and information sharing between distributed actors, such as the fire crews and the command centre operators.

The design process resulted in a low-fidelity web-application to provide functionality to mediate information that is typically stored in orga-

nizational information repositories such as property information. Features were designed to allow information sharing on an ad-hoc basis for a specific incident as part of the response work. Further, a limited message board was also provided in order to provide functionality to share information emerging during the response work. The web application was developed using cgi/perl and html and due to its low-fidelity design it is available for any mobile device with a web browser and internet-connection.



Screenshot of the Incident Web user interface

Incident Web in action

The Incident web was used in a series of field experiments. In the first field experiment involving two incident commanders and one command centre operator, Incident web was used to explore information-sharing based on geographical and risk information distributed by the command centre operator. Two senior commanders were provided with a tablet PC with UMTS-internet connectivity. The command centre operator used a desktop PC in the command centre work setting. The senior commanders communicated over cell-phone with the command centre operator and requested maps, documents and aerial photos covering different aspects of the incident commanders' location. This field-experiment had insignificant levels of time-criticality. Nevertheless, in the relevant context, it served the purpose of making an initial test and exploring how information-sharing could be supported by very simple means. Further, the experiment did also function as a test if commercial UMTS-connections had enough 'real' capacity to transfer emergency response related data. Reflections by the command centre operator and the incident commanders concluded that a) the data transfer capacity was acceptable, b) using a web browser to access incident specific information was easy and provided a sense of familiarity with other applications, c) requesting information involved a degree of negotiation between the actors in order to determine the content to deliver. Based on these results, the next step was a field experiment where the prototype was exposed to a time-critical work setting.

In the following field experiment, the fire crew was equipped with two tablet PCs running incident web application. The fire crew commander used one prototype and the second prototype was used by the firefighters. The time-critical dimension of this field experiment was targeting the issue of how the fire crew and fire crew commander would be able to use the prototype in the dynamic use context. A key concern was to identify how the fire crew commander and fire crew would use the system in relation to a relative short mobilization phase. The following excerpt illustrates how the prototype was used in the interaction between the fire crew commander (FCC) and a company representative (CR) during the initial situation assessment.

TIME [1]	ACTOR	CONVERSATION	COMMENTS/GESTURES
09:14	FCC:	What sort of things do you have up there?	Pointing at the building blueprint on the screen.
09:16		*Radio call from the firemen informing that they are at the top floor.*	
09:25	CR:	It is the location to count all the garments	
09:29	FCC:	Garments.	
09:30	CR:	It is a loading station up there and we send it all down through pipes on the other side of that wall.	Pointing on screen.
09:36	FCC:	Okay.	
09:39	FCC:	Where do you.... where do you store the hazardous material...it says you have 2000 litres.	Switching view to objectinfo.

09:50	CR:	Yepp, it is stored in the room thirty meters down this hall on the right side.	Pointing with his hand down the corridor.

Table: Communication excerpt of Incident Web use

[1] Minutes and seconds

The excerpt illustrates how the prototype is providing means in order to make the situation assessment based on information covering both building layout and hazardous material. The company representative provides location specific knowledge, which helps the fire crew commander in understanding not only the building specific structural properties but also the very activities taking place in the building. The results from this field experiment, in detail presented in paper 5, show how a condensed interaction-time window formed the users' interaction with the prototype.

5.3 Patterns of practice

The section presents a conceptualization of emergency response work practice using sensemaking theory as an analytical lens. The patterns of practice make visible important aspects of emergency response work practice that previous studies have paid no attention to. The three patterns of practice illustrate also that sensemaking theory is applicable to analyze and to conceptualize emergency response work. These patterns are generic in all emergency response work. Each pattern has its specific characteristic that influences the emergency responders' actions. In this thesis, these patterns are addressed with the objective of designing information technology that could support the time-critical work of emergency response. The three patterns and characteristics are; mobilization and initial expectations, intervention and the construction of emergency context, and situational adjustment and the transformation of ambiguity into risk. Based on these patterns of practice, two general design dimensions are presented in section 5.4 and 5.5, addressing key features for designing information technology to support emergency response work. These two dimensions are applicable across the three patterns of practice.

5.3.1 Mobilization and initial expectations

When emergency responders are mobilized and dispatched to an accident location, they start to prepare for the task and situation they expect to face on arrival. However, there is often a difference between what one expects and what is eventually encountered.

Conversation among the firefighters and individual preparations such as mental simulation are also understood as important activities enroute to the accident location. The collective and individual preparation produces expectations formed by the fragmented information at dispatch, contextualized by the firefighters' knowledge and of the accident location and experiences of similar accidents. When the gap between what one expects and what one encounters is significant, it takes time and effort to shift focus to bring forward additional aspects of the new situation and to make sense of the situation. Therefore, information delivery is understood as critical during the few minutes from dispatch to arrival to the accident location. Information delivery does not exclusively include accident information provided by the caller and mediated by the command center. As is shown in paper 1 and paper 5 it includes location specific information that can trigger the firefighters' prior experiences related to the specific accident. Location specific information involves maps, building blueprints as well as object specific information or hazardous material information. The combination of situation specific information with location specific information provides the key material for the ability to make sense of an accident and to rapidly align expectations to what is encountered. During transportation to the accident site, information such as maps, building blueprints and hazardous material information does not only describe what the firefighters will encounter in terms of location but it also triggers the preparations to what they could encounter in terms of situation. The information is critical in order to contextualize the specific emergency and to orient the firefighters' expectations to what is plausible in relation to the fragmented and sometimes ambiguous incident information.

5.3.2 Intervention and the construction of emergency context

The physical intervention by the emergency responders consists of immediate actions to target the urgent needs for the people harmed or at risk by the accident. These actions provide material to make sense of the situation by putting new aspects of the accident context in focus. The objects on the accident site are real but the meaning of them might differ among the emergency responders and they are open for interpretation.

By putting certain aspects in focus and negotiate the meaning of them, an enacted accident environment is formed. The process of constructing and enacting an emergency environment is highly dependent on the ability to interact and share information within the evolving network of emergency responders. Paper 4 illustrates how temporal aspects affect how information might be shared and how the work rhythm of the intervention affects when and how emergency responders make time for interaction. Paper 5 illustrates how the construction of the emergency environment is highly dependent on the capacity of the involved actors in the response work. In order to increase the capacity to make sense of a large-scale emergency, new competences are needed. These competences are found in professionals in external organizations. The capacity to make sense of a large-scale emergency is highly dependent on the ability to organize and manage an evolving network of actors. The inclusion and legitimizing of actors affect the construction of the emergency response context. The key concern here is how to organize this evolving network of actors and to include only those actors that will improve the capacity to make sense of the emergency.

5.3.3 Situational adjustment and the transformation of ambiguity into risk

A key issue in emergency response work is to reduce ambiguity. The time-critical qualities in emergency response caused by limited or fragmented information means that even in routine incident work, some degree of ambiguity always exists. This means that ambiguity needs to be addressed by actively transforming ambiguity into risk (Weick, 1988). Such actions are of crucial importance in emergency response work and take place in interactions between emergency responders, external actors and people. Effective interactions are dependent on a successfully organized response network. When a response network is organized, the capacity to make sense of ambiguous situations improves. Interactions, such as conversations between the emergency responders, professional actors and people, produce the material for sensemaking resulting in a transformation of ambiguity into risk. When ambiguity has been transformed into risk, new meanings of the situation will emerge and form the subsequent actions.

By transforming ambiguity into risk, the response actors could thereafter apply routines, material and personnel to address the specific risks. However, this works also in the opposite direction. The actions and interactions with people form how ambiguity could be transformed into risk. There is a strong agreement among emergency responders that the initial actions set the stage for the work that follows. The relationship between the organizing of a response network and the transformation of ambiguity into risk is presented in paper 4.

Emergency response work is time-critical and characterized by temporal rhythms. The design of information technology use must therefore be aligned to these patterns of practices. Innovative design solutions only provide minor value if the intended users have limited time to use such technologies. The patterns of practice are therefore an important conceptualization that could be used to verify design concepts or prototypes.

5.4 Designing for social interactions

This section presents the design dimension addressing the need of focusing the design of information technology on the social interactions in response work. The design of information technology for emergency response work should focus on the information that becomes manifested in the social interactions between emergency response actors. Designing for social interactions is influenced by the work on enhancing informal interaction (Hindmarsh, Heath, Lehn & Cleverly, 2005) in distributed settings. In contrast, the focus here is to enhance professional interaction in order to support sensemaking activities in response work.

A particular role in emergency response work is not isolated from the ongoing work. This has resulted in suggestions for a role-based design of IT (Turoff et al, 2004) for emergency response. But perhaps even more important, specific focus should be put on the social interactions associated with a specific role. Formal and informal roles and functions are to some extent interrelated with other actors also involved in the response work. Independent of the organizational affiliation of a particular emergency responder, incident specific information will always be a fundamental resource for sensemaking in emergency response work. Social interactions where sensemaking activities take place focus on issues that could be characterized along two interrelated information dimensions; *location – situation* and *actor – actions*. These two information dimensions are here identified as fundamental in the ongoing construction of an emergency context.

5.4.1 The Location – Situation dimension

The location – situation dimension consists of information related to the geographical location and information related to a description of the situation of a particular emergency. One could also view this dimension as targeting the question of *knowing where* and *knowing what* (paper 1) in relation to an emergency. Information technology has a huge potential in innovating emergency response work by improving how location–situation information becomes available for the response actors.

System functionality to provide location specific information to a range of mobilizing response actors is a key issue for a successful intervention. Location specific information is produced as a result of the day-to-day activities of accident prevention and incident preparedness. Subsets of such information consist of geographical information, technical instructions and hazardous material descriptions that need to be structured in order to be operationally available for field-operative actors in cases of emergencies. Further, information about a situation, even if very brief or fragmented will affect and form how the response work will become organized.

Situation specific information is a type of snap-shot information saying something about how someone currently comprehends the situation. Such information is generated directly when emergency responders identify the occurrence of an emergency. The caller or technical installation triggering an alarm provides a range of important situation specific information. When emergency responders arrive to the accident location, the situation specific information increases dramatically. Such information is highly dynamic and is very likely to change during the response work. Instances of situation information are found in status reports and in on-site situation briefings as presented in detail in paper 3 & 4. Location and situation specific information is critical in order for actors to manage expectations during mobilization and to form actions during intervention as described in paper 1, 2 & 5. Location and situation information is tightly intertwined and the lack of one or the other will significantly reduce the capacity for successful response work.

5.4.2 The Actor – Action dimension

However, location and situation-specific information is only one part where information technology could provide innovate features to support emergency response work. In response work, there is always a temporal delay regarding when different actors will become involved in the work. Some organizations are more rapid in responding to accidents, whereas others have less rapid reaction abilities. This means for example that different actors will arrive at different times to an accident location. In large-scale emergency response work, key concerns are to identify the number of actors currently involved in the response work, perhaps even more difficult, to have a sense of what they are doing. This type of information forms the actor-action dimension. Due to the time-critical aspects of emergency response work and the temporal structuring of such work, significant efforts are put on activities to organize the number of actors that becomes involved in the response work.

The arrival of resources from the own organization and the inclusion of these resources in the response work are managed in physical face-to-face interactions as is shown in paper 3. The inclusion of additional resources, either on location or distributed, affect the work rhythm of the response work and is highly dependent on an overview of what other actors are currently involved in on the accident location (Paper 3). In large-scale emergencies, the arrival of actors is significant and the ability to have an overview of all actors is difficult. On-site conferences with all the included actors are understood as important activities to get an updated picture of the involved actors and to talk about the situation and the ongoing work (Paper 4).

5.4.3 Features to provide shared use of information

Emergency response is a highly collaborative activity involving a significant number of actors. Each actor from a range of organizations becomes involved in the response work having their own perspective of the emergency. Interactions between the actors provide the means to construct an emergency context that forms the response work and vice versa. As outlined above, information that is exchanged in these interactions covers the information dimensions of Location-Situation and Actor-Actions. Information technology designed to support emergency response work should include features that improve the ability to explicitly exchange information in such social interactions. A primary feature is to support the shared use of information based on a view that information during an incident is a common resource. Such a feature implies the ability to

provide information sharing mechanisms and mechanisms to keep information accessible for the involved actors. Information emerging during response work needs to become commonly available and not restricted for the actors due to organizational or system boundaries as part of the response work. This means that information technology currently in use in emergency response organizations must be redesigned to provide features that allow for information sharing between actors that are collaborating in an emergency. In order to provide such features, more focus must be put on the social interactions part of such work and less focus on the information needs for a particular role or task. By designing such features, a sense of collaborative visibility could be established which could significantly improve the time-critical formation of an intervention.

5.4.4 Features to accommodate for condensed interaction time-window

Providing features that allow shared use of information would only provide minor value if the intended users have limited time to use such information. This, perhaps obvious reflection, calls for additional features. Information technology must also account for situations of condensed interaction-time window. The time-critical aspects of emergency response work affect the actors' ability to focus on explicit time-consuming interaction with information technology. Features must be designed to enhance a particulars actor's ability to use the technology (paper 5) as an embedded activity by minimizing the gap between technology use and physical response work, as illustrated in the patterns of practice.

Information technology must be designed based on a deep understanding of the contextual aspects of emergency response work, and the constraints such work context put on information technology use. By carefully taking into account how emergency responders conduct their collective work and how their individual tasks are interrelated in such time-critical work, important social interactions will become visible where information technology not only could be used but where it will improve the sensemaking activities embedded in such social interactions. Features providing shared use of information, carefully accommodating a condensed interaction time-window, targets one of the key features of sensemaking, namely that such activities are a collective effort taking place in social interactions between people.

5.5 Designing for traces of actions

Emergency response actors use a range of information technology artifacts in emergency response work such as radios, mobile phones, vehicle navigators and computers. This means that an increasing portion of all interactions between emergency responders will be mediated using information technology. When emergency responders make an intervention to an emergency, their actions will be oriented to fill potential gaps related to location-situation and actors-action information dimensions described earlier. This means that what they do and what they find is relevant for other actors they collaborate with. The use of information technology is related to both individual and collective work tasks, for example querying the hazardous material database for a specific substance, or calling someone over the phone to get a situation update. As a consequence, these interactions will produce a range of digital traces (Grudin, 2002; Jessup & Robey, 2002) simply by the use of radios, mobile phones, navigators and computers. Such traces of action say something about the ongoing work. The information in such computer-mediated interactions is of value for additional actors. The time-criticality and work rhythm in emergency response work restrict many actors' ability to explicitly share information by other means than verbal communication. By using digital traces of interactions, new ways of sharing information and making visible information as a common resource are possible. By making use of digital traces of interactions, a range of new features could be designed.

5.5.1 Features to make ephemeral conversations persistent

Verbal communication is fundamental in emergency response work and verbal communication tends to increase in ambiguous situations (Dunn, Lewandowsky & Kirsner, 2002). This means that how people talk and what they talk about says something about the situation they experience. In emergency response work, verbal communication is often seen as a problem and attempts have been made to improve verbal communication technology for that reason (Camp et al, 2000). One of they key problems with verbal communication in time-critical work is its ephemeral qualities making it difficult to take part of a communication sequence that has already occurred.

Studies of network technicians have shown that transformation of verbal communication into a persistent form decreased the cognitive load in

problem solving work (Rogers & Brignull, 2003). One of the key functions of verbal communication in emergency response work is to provide situation reports and to communicate the ongoing actions of a particular actor. However, the ephemeral qualities of verbal communication make the distribution of information embedded in such conversations difficult. Aspects of the information get lost and it is time-consuming to re-communicate information to a large network of actors. There is a need to transform verbal communication from a state of ephemerality to persistence in order to make information in such conversations digitally accessible.

Making verbal communication persistent will not only enforce accountability but also provide means to structure and make the communication visible and accessible as part of the emergency response work. Collections of persistent verbal communication could be used to provide an evolving structure of communication that would correspond to, and make visible, the ongoing response work.

In order to make action visible in emergency response work (paper 3), new features need to be designed for personal communication devices for emergency responders. Making verbal communication persistent means in the most practical sense that the communication sequences are recorded, tagged (time and sender id) and stored as audio-clips. Further, features must also be designed to visualize these communication sequences in a structure that is dynamically updated as long as the response work is ongoing. These structures would allow new ways of making visible the work structure as a resource for sensemaking as part of the ongoing work.

As concluded in paper 3, this means that the evolving collection of verbal communication sequences would correspond to and make visible the unfolding and gradually clarifying picture of the emergency. Making action visible addresses the aspect of people making sense by the enlargement of small cues in a stream of ongoing experiences.

5.5.2 Features to use contact points as an infrastructure for information sharing

Emergency response work is to a large extent about continuous organizing and re-organizing of resources and people. In such work, the involved actors' contact information is a key resource. Mobile phones are critical information technology artifacts in emergency response work for communication between response groups (Farnham et al, 2006). One of the key aspects of the mobile phone is that the phone number provides the only fixed address to otherwise flexible, independent and mobile individuals (Arnold, 2003).

In a study of two large-scale emergencies (paper 4) it was shown how exchanges of mobile phone numbers between various actors were a fundamental activity in organizing a response network. Even if the current use of mobile phones in emergency response work is to mediate verbal communication, the use of mobile phones also provides the ability to socially form and manage a network of actors across organizational boundaries in response work. Such network of actors becomes manifested in the list of names and phone numbers exchanged between actors and documented in personal note books and in command logs. The accumulation of digital contact information in the actors' mobile phones provides the material to structure a network of actors as the foundation for an information infrastructure improving the ability to share information across the network of response actors (paper 4).

When new actors are included in the response network, through the exchange of mobile phone numbers or mobile phone interaction, they would instantly get access to the information infrastructure. As long as the response is ongoing, the incident specific information infrastructure will also be available. When the acquired phone number is added to the information infrastructure it could typically result in a message that is pushed to the corresponding communication device and thereby providing authorization and access. The addition of contact information should be supported at all localities where contact information such as mobile phone numbers are managed; via the mobile phones of field personnel, at on-location command vehicles, and also the command centre.

5.5.3 Features to make actors and actions visible

The features of making ephemeral verbal communication persistent and features to establish information infrastructure by making use of digital traces of interactions will also provide material to make the involved actors more visible. The two features will produce material that could be visualized in structures representing the involved actors, the relationships between the actors, the communication intensity, and individual conversations. The visualization of the digital traces should be accessible on personal communication devices and used to provide cues and structures for

sensemaking as part of the actors' ongoing response work.

Making such information visible or commonly available (Robertson, 2002) is an important feature not only to support the collaborative work but to shape individual actions so that they are meaningful in relation to others' actions, especially if such actions are part of activities to make sense of an emergency. Features to make actors and actions commonly available, in the emergency response context, improve the involved actors capacity to make sense of time-critical ambiguous situations.

6 Conclusion

This thesis has shown how social interactions are the fundamental underlying mechanism of emergency response work. The findings show that information technology should be designed to support the enacted sensemaking formed in social interactions. Information technology used by emergency responders in emergency response work has embedded qualities that contrast to the formal structure of the larger emergency response system. This means that when designing information technology to responders in emergency response work, a balance must be negotiated between the social mechanisms of information technology use and the formal structure of the larger emergency response system.

Finally, the objective outlined in the beginning of this thesis was to answer the question how can information technology be designed to support emergency response work. This question has been addressed by pointing to three important issues in order to design information technology for time-critical work and especially when designing for emergency response work. These issues are:

- The importance of carefully embedding the use of information technology in the situated work illustrated in the patterns of practice (section 5.3) of time-critical work.
- Design information technology that improves information sharing in social interactions (section 5.4).
- Make use of digital traces of actions (section 5.5) in order to provide collaborative visibility of the work, which will improve the capacity for sensemaking in time-critical ambiguous events.

Information technology has the capability of supporting sensemaking activities but the quality of the outcome of such efforts are difficult to assess. Information technology could improve the activities used to form meaning in equivocal situations. The main challenge for emergency responders is to use whatever resources available to intervene and make sense in ambiguous situations calling for immediate response. Such intervention is a collective effort of actors from a range of organizations. In social interactions among these actors, available fragmented information

is used as conversational grounding to make sense. The reality of response work is not a static activity based solely on pre-defined action plans and fixed organizational roles. Rather, the work is characterized by an ongoing effort of building and maintaining a network of actors where necessary actions are negotiated and formed. Information technology should therefore be designed to support the ongoing organizing of the evolving response network.

The role of information technology is to provide features that improve the organization of the response work as part of the physical intervention work. Information technology use in such collective work has the potential for improving the activities people engage in when making sense. However, as Karl Weick warns, the very design of information technology will also pre-structure what people will treat as their world (Weick, 1995). By providing improved features of information technology for people to share information and allow new ways of visualizing the ongoing time-critical work, emergency responders will become better equipped in sensemaking activities.

7. References

Anderson, R.J. (1994) Representations and Requirements: The value of ethnography in system design, *Human-Computer Interaction.* (9), 151-182.

Andersson, M., & Lindgren, R. (2005) The Mobile-Stationary Divide in Ubiquitous Computing Environments: Lessons from the Transport Industry, *Information Systems Management.* (22)4, 65-79.

Arnold, M. (2003) On the phenomenology of technology: the Janus-faces of mobile phones. *Information and Organization.* (13)4, 231-256.

Bigley, G. A. and K. H. Roberts (2001). The Incident Command System: High-Reliability Organizing For Complex and Volatile Task Environments. *Academy of Management Journal* (44)6, 1281-1300.

Blomberg, J., Giacomi, J., Mosher, A., and Swenton-Wall, P. (1993) Ethnographic Field Methods and Their Relation to Design, In: *Participatory Design: Principle and Practices,* A. Namioka (ed.), Lawrence Erlbaum Associates Publishers, Hillsdale, New Jersey.

Brehmer, B. (1991). Modern information technology: Timescales and distributed decision making. *Distributed Decision Making: Cognitive Models for Cooperative Work.* J. Rasmussen, B. Brehmer and J. Leplat (ed.), John Wiley & Sons, 193-200.

Brehmer, B. (1998). Distributed Decision Making In Dynamic Environments. *In proceedings of the 4th International Command and Control Research and Technology Symposium,* Näsby Park, Sweden.

Britton, N. (1989). *Anticipating the Unexpected: Is the bureaucracy able to come to dance*. Working WP1. Cumberland College of Health Sciences, Disaster Management Studies Centre, Sydney.

Buck, D., Trainor, J., & Aguirre, B. (2006). A Critical Evaluation of the Incident Command System and NIMS. *Journal of Homeland Security and Emergency Management*. 3(3).

Button, G. (2000). The ethnographic tradition and design. *Design Studies.* 21(4), 319-332.

Burke, E. & Hendry, C. (1997). Decision making on the London incident ground: an exploratory study. *Journal of Managerial Psychology.* (12)1.

Camp, P., Hudson, J., Keldorph, R., Lewis, S., & Mynatt, E (2000). Supporting communication and collaboration practices in safety-critical situations. In *proceedings of the 2000 Conference on Human Factors in Computing Systems,* The Hague, The Netherlands, ACM Press, New York, NY, USA.

Chen, R., Sharman, R., Rao, H., Upadhyayaet, S. (2005). Design Principles of Coordinated Multi-incident Emergency Response Systems. In *proceedings of the 2005 IEEE International Conference on Intelligence and Security Informatics,* ISI 2005, Atlanta, GA, USA, Springer Berlin / Heidelberg.

Crabtree, A. (2003). *Designing Collaborative Systems*. London: Springer-Verlag.

Cronan, K. (1998). Foundations of Emergency Management. *Australian Journal of Emergency Management*. (13)1, 20-23.

Drabek, T. & McEntire, D. (2003). Emergent phenomena and the sociology of disaster: lessons, trends and opportunities from the research literature. *Disaster Prevention and Management*. (12)2, 97-112.

Dunn, J. C., Lewandowsky, S., & Kirsner, K. (2002). Dynamics of communication in emergency management. *Applied Cognitive Psychology.* (16)6, 719-737.

Dynes, R. (1994). Community Emergency Planning: False Assumptions and Inappropriate Analogies. *International Journal of Mass Emergencies and Disasters*. (12), 141-199.

Emerson, R. Fretz, R. & Shaw, L. (1995). *Writing Ethnographic Fieldnotes*. Chicago, The University of Chicago Press.

Farnham, S., Pedersen, E. & Kirkpatrick, R. (2006). Observation of Katrina/Rita Groove Deployment:Addressing Social and Communication Challenges of Ephemeral Groups. In *proceedings of the 2006 International ISCRAM Conference,* Newark, NY, USA.

Fetterman, D. (1998) *Ethnography - Step by Step*. Sage Publications, Thousand Oaks, California.

Flin, R. (1996). *Sitting in the Hot Seat: Leaders and Teams for Critical Incidents*. Chichester, Wiley.

Forsythe, D.E. (1999)"It's Just a Matter of Common Sense": Ethnography as Invisible Work, *Computer Supported Cooperative Work* (CSCW). (8)1-2, 127-145.

Fredholm, L. (1997). Decision-making patterns in major firefighting and rescue operations. Decision Making under stress: *Emerging themes and applications.* R. Flin, E. Salas, M. Strub and L. Martin (eds.) Vermont, USA, Ashgate Publishing Company.

Grudin, J. (2002). Group dynamics and ubiquitous computing. *Communications of the ACM* (45)12, 74 - 78.

Hammersley, M. & Atkinson, P. (1995) *Ethnography*. Routledge, London

Hale, J. (1997). A layered communication architecture for the support of crisis response. *Journal of Management Information Systems*. (14)1, 235-256.

Harvey, L.J., & Myers, M.D. (1995). Scholarship and practice: the contribution of ethnographic research methods to bridging the gap, *Information Technology & People.* (8)3, 13-27.

Heath, C. and J. Hindmarsh (2002). Analysing Interaction: Video, ethnography and situated conduct. *Qualitative Research in Action.* T. May (ed.). London, Sage. 99-121.

Heath, C. and Luff, P. (1992). Collaboration and Control: Crisis Management and Multimedia Technology in London Underground Line Control Rooms. *Journal of Computer Supported Cooperative Work.* (1)1, 24-48.

Heath, R. (1998). Dealing with the complete crisis -the crisis management shell structure. *Safety Science.* (30)1-2, 139-150.

Hendfridsson, O. (1999). *IT-adaptation as Sensemaking.* PhD-Thesis. Umeå University, Sweden.

Hindmarsh, J., Heath, C., Lehn, D.,Cleverly, J. (2005). Creating Assemblies in Public Environments: Social Interaction, Interactive Exhibits and CSCW. *Computer Supported Cooperative Work* (CSCW). (14)1, 1-41.

Hughes, J.A., Randall, D., and Shapiro, D. (1992). Faltering from ethnography to design, In proceedings of the 1992 *Conference on Computer Supported Cooperative Work: Sharing Perspectives* (CSCW92), New York, NY

Hughes, J., King, V., Rodden, T. & Andersson, H. (1995). The role of ethnography in interactive systems design, *Interactions*, (2)2, 56-65.

Jessup, M. & Robey, D. (2002). The relevance of social issues in ubiquitous computing environments. *Communications of the ACM.* (45)12, 88-91.

Jiang, X., Chen, N., Hong, J., Wang, K,. Takayama, L., Landay, J. (2004). Siren: Context-aware Computing for Firefighting. In *proceedings of the 2004 Conference on Pervasive Computing*. Vienna, Austria.

Jiang, X., Hong, J., Takayama, L., Landay, J. (2004). Ubiquitous computing for firefighters: field studies and prototypes of large displays for incident command. In *proceedings of the 2004 conference on Human factors in computing systems*. Vienna, Austria, ACM Press, New York, NY, USA.

Jungert, E., Hallberg, N. & Hunstad, A. (2006). A service-based command and control systems architecture for crisis management. *Interational Journal of Emergency Management*. (3)2-3,131-148.

Kayes, C. (2004). The 1996 Mount Everest climbing disaster: The breakdown of learning in teams. *Human relations.* (57)10.

Klein, G., Calderwood, R. & Clinton-Cirocco, A (1988). *Rapid decision making on the fire ground.* Alexandria, Klein and Associates Inc, U.S Army Research Institute for the behavioural and social sciences, report108.

Klein, G. (1993). A recognition-primed decision (RPD) model of rapid decision making. *Decision making in Action: Method and Models.* Klein, Calderwood, Zsambok, Ablex (eds.), 138-147.

Klein, G. (1997). An overview of Naturalistic decision making applications. *Naturalistic Decision Making*. C. E. Zsambok and G. Klein (eds.). Mahwah, New Jersey, Lawrence Erlbaum Associates, 49-59.

Kristensen, M., Kyng, M. & Palen, L. (2006). Participatory design in emergency medical service: designing for future practice. In *proceedings of the 2006 conference on Human Factors in computing systems,* Montréal, Québec, Canada, ACM Press, New York, NY, USA.

Kyng, M., Nielsen, E., & Kristensen, M. (2006). Challenges in designing interactive systems for emergency response. In *proceedings ot the 2006 conference on Designing Interactive systems*, University Park, PA, USA, ACM Press, New York, NY, USA.

Manning, P. K. (1996). Information Technology in the Police Context- The "Sailor" Phone. *Information Systems Research*. (7)1, 52-62.

Marcus, A. & Gasperini, J. (2006). Almost dead on arrival: a case study of non-user-centered design for a police emergency-response system. *Interactions*. (13)5.

Meissner, A., Luckenbach, T., Risse, T. & Kirste, H. (2002). Design Challenges for an Integrated Disaster Management Communication and Information System. In *proceedings of the 2002 IEEE Workshop on Disaster Recovery Networks (DIREN 2002)*. New York City.

Mogensen, P., & Trigg, R. H. (1992). Artifacts as triggers for participatory design. In *proceedings of the 1992 Participatory Design Conference*. Boston: Computer Professionals for Social Responsibility.

Myers, M. (1999). Investigating information systems with ethnographic research. *Communications of the AIS*. (2)4.

Neal, D. & Phillips, B. (1995). Effective emergency management: reconsidering the bureaucratic approach. *Disasters* (19), 327-264.

Normark, M. (2002). Sense-making of an emergency call: possibilities and constraints of a computerized case file. In *proceedings of the 2002 nordic conference on human-computer interaction.* Aarhus, Denmark, ACM Press New York, NY, USA.

Nulden, U. (2003a). Investigating police patrol practice. In *proceedings of the 2003 conference on Human Factors in Computing Systems (CHI2003)- New Horizons.* Ft. Lauderdale, Florida, USA, ACM Press.

Nulden, U. (2003b). Police Patrol Mobility. In *proceedings of the Information systems research seminars in Scandinavia (IRIS 26),* Haikko Manor, Finland.

Orasanu J & Connolly T (1992). The reinvention of decision making. *Decsion making in action, models and methods.* G. Klein, J. Orasanu, R. Calderwood & C. Zsambok (eds.). Norwood, New Jersey, Ablex Publishing Corporation.

Orlikowski, W. (1992) Learning from notes: organizational issues in groupware implementation, In *proceedings of the 1992 conference on computer supported cooperative work: sharing perspectives* (CSCW92). ACM Press, New York, NY

Orlikowski, W. J. & Gash D. C. (1994). Technological Frames: Making Sense of Information Technology in Organizations. *ACM Transactions on Information Systems.* (12)2, 174-207.

Orlikowski, W. & Yates, J. (2002). It´s about time: Temporal structuring in Organizations. *Organizational Science.* (13)6, 684-700.

Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods*. London, United Kingdom, SAGE Publications.

Perry, R. (2003). Incident management systems in disaster management. *Disaster Prevention and Management*. (12)5, 405-412.

Pettersson, M. (2004). WaterCalls: an ambient call queue for cooperation between emergency service centres. *Personal and Ubiquitous Computing*. (8)3-4).

Pettersson, M., Randall, D., Helgesson, B. (2002). Ambiguities, awareness and economy: a study of emergency service work. In *proceedings of the 2002 conference on computer supported cooperative work*. New Orleans, Louisiana, USA, ACM Press, New York, NY, USA.

Phillips, B. (2002). Qualitative Methods and Disaster Research. *Methods of disaster research*. R. Stallings (ed.), International Research Committee on Disasters, 194-211.

Pica, D. & Sorensen, C. (2005). Tales from the police: Rhythms of interaction with mobile technologies. *Information and Organization*. (15)2, 125-149.

Pink, S. (2002). *Doing Visual Ethnography*. London, SAGE Publications Ltd.

Reddy, M. & Dourish, P. (2002). A finger on the pulse: temporal rhythms and information seeking in medical work. In *proceedings of the 2002 conference on computer supported cooperative work*. New Orleans, Louisiana, USA, ACM Press, New York, NY, USA.

Robertson, T. (2002). The Public Availability of Actions And Artifacts. *Computer Supported Cooperative Work*. (11), 299-316.

Rogers, Y., & Brignull, H. (2003). Computational Offloading: Supporting Distributed Team Working Through Visually Augmenting Verbal Communication. In *Proceedings of the 25th Annual Meeting of Cognitive Science Society.*

Schneider, S. (1992). Governmental response to disasters: The conflict between bureaucratic procedures and emergent norms. *Public Administration Review*. (52)2, 135-145.

Shen, Z., Yoo, Y. & Lyytinen, K. (2006). Temporal Implications of Information Technology for Work Practices: Organizing in and for Time in an Emergency Department. In *proceedings of the 2006 Hawaii International Conference on System Sciences*. Hawaii, USA.

Smircich, L. and Stubbart, C. (1985) Strategic Management in an Enacted World. *The Academy of Management Review*. (10)4, 724-736.

Snook, S. (2000). *Friendly Fire*. New Jersey, Princeton University Press.

Snow, D. Morrill, C. Andersson, L. (2003). Elaborating analytic ethnography - Linking fieldwork and theory. *Ethnography* (4)2, 181-200.

Stephenson, R. & Andersson, P. (1997). Disasters and the Information Technology Revolution. *Disasters*. (21)4, 305-334.

Suchman, L. (1987) *Plans and Situated Actons - The problem of Human-Machine Communication*. Cambridge, UK: Cambridge University Press.

Turoff, M. (2002). Past and future emergency response information systems. *Communications of the ACM* (45)4, 29-32.

Turoff, M., Chumer, M., Van de Walle, B. & Yao, X. (2004). The Design of a Dynamic Emergency Response Management Information Systems (DERMIS). *Journal of Information Technology Theory and Application*. (5)4.

Twidale, M., Randall, B. Bentley, R. (1994). Situated Evaluation for Cooperative Systems. In *proceedings of the 1994 conference on computer supported cooperative work* (CSCW94), Chapel Hill, North Carolina, United States, ACM Press New York.

Wacquant, L. (2003). Ethnografeast, *Ethnography* (4)1, 5-14.

Weick, K.E. (1979). *The Social Psycology of Organizing*. McGraw-Hill. 2nd Edition.

Weick, K. E. (1988). Enacted sensemaking in crisis situations. *Journal of Management Studies*. (25)4, 305-318.

Weick, K. E. (1990). The Vulnerable System: An Analysis of the Tenerife Air Disaster. *Journal of Management*. (16)3, 571-594.

Weick, K. E. & Meader, D. (1992). Sensemaking and Group Support Systems. *Group Support Systems: New Perspectives*. L. Jessup and Valacich (eds.), Macmillan Pub Co, 230-251.

Weick, K. E. (1993). The collapse of sensemaking in organizations: The Mann Gulch disaster. *Administrative Science Quarterly*. (38)4.

Weick, K. E. (1995). *Sensemaking in organisations*. Thousand Oaks, SAGE Publications Inc.

The papers

Paper 1

Supporting fire crew sensemaking enroute to incidents

Jonas Landgren

Abstract

Reconstruction of major emergencies and crisis as well as observations of large-scale emergency exercises are common approaches for studying and understanding various actors work practice in emergency response. Studies of small-scale emergencies using an ethnographic approach are less common. This paper presents data from a single small-scale emergency as part of an extensive ethnographical field study. A detailed analysis of fire crew enroute sensemaking in a single small-scale emergency is outlined. The theory of sensemaking is applied as an analytical lens aiming to explain the communication between the command centre operator and the fire crew in terms of sensemaking. Further, implications for design of information technology use for fire crew enroute sensemaking will be presented as well as brief reflections of the consequences of such design.

Keywords

Fire crew, incident commander, emergency response, sensemaking, ethnography, design implications

1 Introduction

Studies of sensemaking in emergency response in major accidents and crisis have shown the importance of analysing the organisational and social processes affecting the actions of the involved actors (Weick, 1988, 1993). Major accidents and crises has been the primary focus for understanding sensemaking in emergency response but little attention has been paid to small- scale emergencies. A small-scale emergency could, if not dealt with adequately, quickly develop into a major crisis (Perrow, 1984). It is therefore advocated in this paper to focus on the sensemaking process in small-scale emergencies and specifically how a fire crew's sensemaking enroute to an incident is affected by limited and ambiguous information, potentially leading to undesirable results. This paper examines the sensemaking process of a fire crew enroute to an incident, using data from one emergency. Based on this, implications for design of information technology use to support sensemaking are suggested. The remainder of the paper is organized as follows. Section two briefly presents related research highlighting different approaches applied to study actors in emergency response. Section three presents the method applied in this study and describes in detail the data collection approach and associated problems. In section four sensemaking is presented as the theoretical foundation and analytical lens. Following to this in section five the results based on the empirical data is presented and related to the theory of sensemaking. In section six the empirical findings are used to propose implications for re-design of the current information technology used by the fire and rescue services. The paper ends with a discussion in section seven and conclusions in section eight.

2 Related Work

Studies of emergency response have a strong tradition to a focus on individual and team decision-making. Several studies have explored commander decision making in major incidents (Klein, Calderwood, Clinto-Cirocco, 1988; Burke, Hendry, 1997) using the *critical decision method*. The aim has been to understand decision-making in field settings and the method of doing this has been retrospective interviews. Studies of radio

talk in large-scale emergency response exercises have focused on the effects of task-specific factors and situation specific factors on the communication pattern between key emergency management team members (Dunn, Lewandowsky, Kirsner, 2002). Studies of commander improvisation in emergency response (Mendoca & Berroggi 2001) have used field exercises to inform the design of decision support systems for field settings. Studies of everyday work of fire crews and small-scale emergencies have not gained much attention. The limited attention could partly be explained by the time-consuming process of such studies.

3 Method

This paper reports from an ongoing extensive field study of every day work at communal fire and rescue services in Sweden. The field study has been conducted using an ethnographical approach (Hammersley & Atkinson. 1995) where approximately 700 hours of participant observations with fire crews has been conducted. Almost nine hours of video ethnography (Pink, 2002) has also been collected. Results from the field study will be used to inform the design of information technology use (Hughes, King, Rodden & Andersson, H. 1995) in operative fire and rescue services. The author has gained access to the fire crew and participated in the fire crew activities on both day and night shifts. When responding to alarms the author has used the mandatory protective clothing. Studying a group of people has presented some difficulties especially on alarms where the crew during enroute are distributed in two vehicles and the author have had his position on the second ladder vehicle, unable to observe the activities in the first rescue vehicle. In order to study the work practice in the first rescue vehicle during enroute, a video camera has been mounted on the dashboard pointing inward in the vehicle. The incident commander has started the video camera directly when he got seated. Field notes has in many cases been written down after the fire crew has left the incident site or back at the fire station.

The combination of field notes and video recordings have been used to triangulate the analysis. Using video data has provided a rich material otherwise difficult to collect and analyse on a micro-level. Transcribed field notes have provided material to analyse and understand the context.

The incident presented in this paper has been selected from a larger collection of observations and video recordings and is a good representation of a typical minor daily incident that constitutes the majority of alarms for fire crews in Sweden. However the specific events in this particular incident provide a good illustration of the typical difficulties confronted during enroute to an incident location and the actor's efforts to make sense of the situation.

4 Theory

The theory of sensemaking is here applied as an analytical lens and is used to analyse the data and validate the findings. Sensemaking is based on the idea that "reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs." (Weick, 1993). According to Weick, sensemaking is not a metaphore but, as the making of sense. Sensemaking and interpretation are highly related concepts but not each others equivalents, "sensemaking is about the ways people generate what they interpret" (Weick 1995, p 13). Sensemaking is understood as a process, consisting of seven characteristics, that is; grounded in identity construction, retrospective, enactment of sensible environments, social, ongoing, focused on and the extraction of cues, driven by plausibility.

The task of the sensemaker is to convert experiences to something meaningful, and fundamentally establishing and maintaining his or her identity. Situations experienced by people are progressively clarified and this clarification emerges when people in retrospect brings the pieces together to create a sensible explanation of the situation. One can only make sense of something after it has been experienced. The time period from experience to the making of sense could be a split second or a rather prolonged period of time. When people act to make sense, they also affect the environment that they are trying to make sense of. This means that people act in a context and this context is shaped by people actions to make sense. When people make sense, it is not an isolated activity but continuously ongoing. Sensemaking is as a social process and part of people's daily social interaction where meaning are established in and influenced by the presence of collective social structures. The context in which sense making occurs affect what cues will be extracted and how these cues are

interpreted as well as the revision of those interpretations based on following actions and their consequences. The making of sense is more oriented towards the plausible than the accurate due to the time criticality in many situations.

People are continuously making efforts to make sense of situations they experience and they do it by looking at a world upon which they already have imposed what they believe (Weick, 2001, p.15). In order for people to make sense, they must act. In sensemaking it is understood that action precedes understanding. People act in some form of social context involving a collective of people, which are affected by the actions or take part in these actions. *"Sensemaking is focused on those actions around which the strongest commitment forms"* (Weick 2001, p.26). Commitment binds the individual to his behavior and influences the individual's further sensemaking.

Committed action determines the scope of interpretation by focusing on those cues that suggest potential justification of that committed action. Commitment is an additive process resulting in a situation where new justifications and meanings slowly emerge due to their ground in old meanings that are to some degree persistent even if they are outdated.

This means that to make sense, people as actors in a social context will interact and make committed actions based on a cues that help them to justify their actions in that particular social context.

In situations characterized by ambiguity and unexpected events people's efforts to make sense becomes visible for analysis. When a group of people are surprised or when they experience that expected events does not occur, people direct their conversation to clarify the blurred and confusing picture, i.e. to make sense. The analysis in this paper is focused on the conversation between the operator, incident commander and the fire crew where commitment, cues and justification affect the behavior of the fire crew.

5 Result

The setting reported from in this paper is a fire crew in a suburban district in a major city in Sweden. The fire crew consists of the incident commander (IC), the fire crew foreman and five firemen, making a total of eight people. In the incident examined here, the fire crew is dispatched by the command centre operator (CCO). The incident response is initiated when a person have called the national emergency organization and reported a fire in what is understood as an electrical power station. The command centre operator dispatches the fire crew, which initiates the drive to the incident location using rescue vehicle 411 and 413. Due to the vague location description by the caller, the CCO and IC face problems to determine the location. The CCO contacts the energy company. Information from the energy company influences the fire crew's actions of the incident.

The data outlines the communication between the command centre operator (CCO), the incident commander (IC), the fire crew foreman and three firemen in rescue vehicle (411) and additional two firemen in the ladder vehicle (413). The observations have been divided in two parts with subsequent detailed analysis.

5.1 Sequence A

This sequence shows how the involved actors are trying to understand and define the incident location and the type of incident. The sequence starts when the fire crew just has left the fire station and the IC establishes contact with the command centre.

#	Time	Actor	**Conversation** (Text in italics represents talk over radio)
01	0.00	IC:	*Four-eleven (411), one-one-three, we are heading for Nuevo-hotel.*
02	0.05	CCO:	*Okay, four-eleven (411), behind Nuevo-hotel along the cycle way there is an electricity-house, says the caller, and there is smoke. You will have eighty-six adam. Over.*
03	0.20	IC:	*eighty-six adam…what company or address did you say?*
04	0.31	Fireman:	you have to decide yourself, John.
05	0.32	CCO:	*no…along the cycle way behind Nuevo-hotel, there is some…a large…an electricity-house…with smoke coming out…contact the energy-company to hear if they have something there.*

06	0.36	**Foreman:**	drive to the backside,.....when you pass the OceanStore.
07	0.41	**Driver (John):**	Okay.
08	0.50	**IC:**	*Sounds good...and you take contact with the energy company.*
09	0.54	**CCO:**	*I´ll do that, Andrew.*
10	1.03	**IC:**	I do not understand what company he is talking about...but...
11	1.07	**Foreman:**	But we should drive behind the apartments... on the back.
12	1.20	**IC:**	Yeah, there is that...that entrance gate.
13	1.28	**IC:**	It will be goblin steps.
14	1.30	**Fireman:**	Yes.
15	1.38	**IC:**	If there is ground current you should not take any big steps. [laugh]

Table: Sequence A

5.1.1 Sensemaking triggered by ambiguity

The location of the incident is vaguely described by the caller making it difficult for the CCO to provide a distinct location to the IC. In parallel to the CCO and IC conversation, the foreman gives route directions to the driver of the rescue vehicle based on ambiguous information. The ambiguity of the information is highlighted by the IC´s response to the CCO requesting a company name or street address, which is the standard method to define an incident location. The reaction from the CCO is an accentuation and repetition of the prior information. The CCO is at this moment in a troublesome position where he is unable to comply with the IC´s request to deliver an adequate incident position. A solution is immediately formed by the CCO when telling the IC that contact will be taken with the energy company, to find out if they have something in the area. The IC supports this action and confirms that the CCO shall make the contact.

The sensemaking triggering event is visible in line 03, when the IC requests company name or address. Having no street address or company name, but rather a vaguely described geographical location, violates what the IC in this situation normally expects.

The conversation (line 05,08,09) shows how the interaction between the IC and CCO results in a commitment, a commitment to take contact with the energy company. Further, this commitment binds the CCO to this agreed action by the IC´s explicit public and irrevocable remark that the CCO shall make the contact. The interpretation of this is that the CCO not only shall make the action but also is responsible for that action. As will be shown later, this commitment will have implications on the following actions presented in sequence B.

5.1.2 Defining the location using reference points

When the conversation with the CCO ends, the IC turns to the foreman and fire crew in the back seat compartment, expressing that he does not understand which company the CCO refers to. The interpretation of this is that the IC has a company as a reference point different to *"behind Nueovo-hotel"* and *"along the cycle-way"* being the compound reference point for the CCO.

The foreman expresses his understanding of the plausible location and describes where they should proceed, without mentioning a company as a reference point but instead a selection of buildings. The IC responds and adds to this picture by mentioning the existence of an entrance gate corresponding to the location presented by the foreman. What is shown here is how the IC and the foreman uses their knowledge about the area and based on each others descriptions extract cues to build a shared understanding. In this particular case, the IC changes reference point from an undefined company to a very detailed reference point consisting of a gate in the local area. Interesting to notice here is that neither the IC nor the foreman explicitly makes any references to the term *"electricity house"*, which based on the CCO information should be the object of attention. This could be explained by the simple fact that an electricity house is not part of the IC's or the foreman's area knowledge and therefore nonrelevant information at this moment.

5.1.3 Describing type of incident

In the opening conversation (line 02), the CCO describes the type of incident by saying *"electricity-house"* and *"there is smoke"* and declaring that this is information provided by *the caller*. The explicit reference that the information is what the caller has expressed implies that this information could be unreliable. In the conversation (line 05), following the IC´s question regarding company or address, the CCO adds the description *"there is some...a large..an electricity house...with smoke coming out"*. The term *"electricity house"* indicates that this incident concerns a fire in an electrical power station. However, the hesitation in the CCO´s description of the constitution of the building makes an indication that this information is potentially uncertain. But, the joke made by the IC (line 13) referring to potential dangers with ground current shows that the IC has to some extent framed his understanding of the incident type.

The analysis of the IC's conversation about the incident suggests a serial sequence where the object of attention is determined by urgency and plausibility. In this incident the urgency concerns the understanding of the location position. Without a satisfying understanding on the location, everything else will become less important. The location description is as previously mentioned, flawed by ambiguity, attributed several meanings. This means that the fire crew could risk ending up at the wrong location, which would extend the time for the fire crew to make the actual response. Focus is therefore on the issue of ambiguity of the location information.

The incident type is plausible, a fire in an electricity house, even if this information is flawed by uncertainty. This uncertainty could be minimized if or when additional calls are made by people on the location or by the fire crew themselves when they arrive to the accident location. This means that it is more important to determine the correct location rather than establishing an understanding what will face the fire crew up on arrival. The fire crew will be able to respond to almost any incident but this requires them to know where to go.

5.2 Sequence B

This sequence shows have the information obtained in the contact with the energy company affects the actions of the fire crew.

#	time[1]	actor	conversation (Text in italics represents talk over radio)
16	2.31	CCO:	*411 to, 400 over.*
17	2.35	IC:	*411 responds.*
18	2.37	CCO:	*I have talked to the energy company, it is the case that they have an electrical power station on the backside at Jellyfishstreet behind Nuevo-hotel and he will send a guy, over.*
19	2.51	IC:	*That's great, then I will know, over.*
20	2.53	CCO:	*That's acknowledged, over and out.*
21	2.58	IC:	Did you hear that a guy from the energy company is also on his way.
22	3.02	Foreman:	Electrical power station, or?
23	3.04	IC:	Yes.
24	3.17	Driver:	Should go...could come that way too, thought if you drove round there and in there.
25	3.22	IC:	Yes...
26	3.23	IC:	Think we shall do that.
27	3.24	Driver:	Yes it feels so.
28	3.25	IC:	Enter Jellyfish street instead.
29	3.26	Driver:	Yes, it feels more [right].
30	3.27	IC:	We´ll do that.
31	3.31	IC:	*413, we enter at Jellyfish street.*
32	3.35	413:	That's acknowledged.

Table: Sequence B

[1] Minutes and seconds

5.2.1 Emerging information

Two minutes after the initial conversation the CCO calls for the IC's attention informing the he has talked to the energy company and that they have an electrical power station on Jellyfish Street behind Nuevo-hotel.

The CCO also informs the IC that the energy company is sending a person to the location. In this conversation the CCO have switched terminology from *"electricity-house"* to *"electrical power station"*. The IC does not comment the shift of terminology but responds to the new information with the general expression *"that's great, then I will know"*.

Immediately after, the IC turns to the firemen and foreman in the backseat compartment and says in a question-like phrase if they heard that the energy company sent a guy. The response by the foreman is a new question *"electrical power station, or?"* to which the answer from the IC is *"yes"*. What is shown here is a committing act where the IC and foreman socially defined the incident type as a fire in an electrical power station. This committing act defines the context and has effects on following actions.

Moments before the rescue vehicle (411) approaches a road intersection the driver suggests an alteration (line 24) of the approach route to better correspond to the newly established understanding that Jellyfish Street is the incident location. The conversation between the driver and the IC about alteration of route show how they construct justification for this route alteration. Prior to the contact with the energy company, Jellyfish Street was never discussed. In sequence A, the IC and foreman agreed on a different accident location. It could therefore be stated that the alteration of the route choice is a result of the information obtained from the energy company and a justification of the previous committed act by the IC and foreman defining the type of incident. As a consequence the route choice is altered in order to align with the socially defined understanding of a fire in an electrical power station at Jellyfish street.

5.2.2 Preferential right of interpretation

What is evident in sequence B is how the fire crew and specifically the IC and foreman and not the CCO, have the preferential right of interpretation. The CCO did not express that the incident concerned a fire in an electrical-power station at Jellyfish Street. However, the committed actions of the CCO, IC and foreman created the environment where this became the only sensible direction. The preferential right of interpretation is not explicitly expressed in the fire and rescue service organization procedures but becomes visible in the actions of the fire crew.

5.3 Epilogue

Further but not part of the scope of this paper, when the fire crew arrives to the perceived location they are unable to use the desired approach route forcing the IC to walk to the building and the driver to choose an alternative approach route. In retrospect it was shown that this incident did not involve a fire in an electrical power station, but a person having started a fire in his fire stove in a garage. The fire crew where not at the location of the electrical power station.

The analysis reveals how the initial and vague information influenced the actors following actions and understanding of the situation. In the chain of interaction it is evident that commitment binds the actors to their actions. Once contact was made with the energy company it became severely hard to ignore the received information. The information flow was suffering of a filtering effect where the IC had to rely on second hand information, becoming third hand information when it reached the fire crew. All information delivered from the CCO was obtained in conversations with external actors; the caller, and the person at the energy company. The filtering effect of the information in this communication chain and the inability of the IC to ask further questions to these actors could partly explain the result of the sense making efforts. Only one information channel delivered information. The lack of other complementary information channels or resources restricted the fire crew's ability to validate and finding inconsistencies.

The analysis reveals how committed action creates the context for sensemaking by narrowing the actors' focus to a subset of cues in the available information that suggest reasonable justification of those actions.

6. Design implications

As presented in the previous section communication between the incident commander and the command centre is challenging and has potential to be improved. Therefore, in this section a set of implications for re-design of current technology use will be presented. The findings presented in the previous section will be linked to a set of suggested functionality aiming

to provide improved support for fire crew sensemaking enroute to an incident. Based on the analysis, two fundamental issues are derived, namely the two issues; knowing where and knowing what.

First, *knowing where* focus on understanding and defining the location of an incident. As presented in the result section, situation specific aspects concerning the alarm have the potential to restrict the fire crew's ability to determine the incident location. Information received along the road might influence alteration to the intended approach route.

Second, *knowing what* focus on understanding and defining the type of incident. The findings in this paper show that this issue is secondary and less important compared to knowing where. However when the knowing where issue is solved the issue of knowing what becomes primary. These two issues will be further elaborated and specific functionality will be proposed in order to support and improve the related work practice.

Knowing where: Fundamental functionality to improve a fire crew's enroute incident sensemaking involves support for a common and mutual representation of the perceived incident location. As shown in section 5.1.1 and 5.1.2 the actors face problems when using different reference points for establishing an understanding of the location. Providing support for mutual representation would result in a situation where the IC and CCO have the same type of information at hand when trying to making sense of an incident. The common representation should include not only street names but contextual information of buildings and descriptive information regarding the various businesses in the buildings. Contextual information could also include information from sensory systems such as fire alarms and property surveillance cameras.

In the time-critical work of getting to the incident location, voluminous information must be avoided. Instead the design must provide rich information without increasing the complexity. A mutual representation using contextual information would extend the range of possible cues for the sensemaking process, making the fire crew more capable to find inconsistencies in portions of the delivered incident information. Having access to mutual representation of the location have the potential to better support the practice of using reference points, as reported of in section 5.1.2, to make sense of the incident specifically when the incident is subjected to ambiguity as reported of in section 5.1.1.

Knowing what: As presented in the section 5.2.1, during enroute the CCO in some cases make external contacts to find additional information regarding a particular incident. This includes contact with various professional organizations in the society but also re-establishing contact with the caller of the specific alarm. Participating in such conversations could be of importance for the IC's understanding of the incident. Further, due to the IC's preferential right of interpretation (section 5.2.2), having access to first-hand information is fundamental and would limit the information filtering effect.

Support should therefore be provided to enable the IC to listen-in to the CCO's conversation with other actors concerning the specific incident. This does not however imply that the IC should handle the administrative efforts to establish such contacts nor forced to having a dialogue, but rather an ability to listen-in and the possibility to ask additional questions when necessary. As reported in section 5.2.1, information is emerging over time as the situation is unfolding. Listen-in support is central in order to coordinate the efforts of the IC, CCO and external actors to make sense of the specific incident. Being able to listen-in to conversations, especially in situations of ambiguity, could improve the IC's ability to establish a broader understanding of the location and the incident type based on a richer set of cues.

In this section, functionality to improve sensemaking has been proposed targeting the core issues of *knowing where* and *knowing what*. A fundamental aspect of the proposed functionality is its ability not only to provide better support for the IC and fire crew but to improve the collaborative work between the CCO and the IC. The proposed functionality does not aim to disconnect the fire crew from the command centre but instead bring the two units closer together. Designing information technology as proposed above have the potential to focus the conversation between the CCO and the IC on the available information instead of spending valuable time to deliver the information by voice. This means that these two actors could have more time to make sense of the information. Providing information technology to the fire crew will not only have consequences for the fire crew but for components in the emergency management system. Therefore, it is important that the design of this technology is done with the ultimate goal to improve the fire crew's ability to make a rapid, efficient and safe response.

7 Discussion

This section offers a discussion of the method, theory, the suggested implications for design and consequences of such design.

Studying a group of mobile people that are geographically distributed, and the sorts of technologies they use or might have use for can from a methodology perspective be challenging (Weilenmann, 2003). In this paper video recording and observation has been the primary data collection methods. The video data was used for two purposes. Firstly, to study the radio communication between the IC and the command centre. Secondly, to study the conversation and actions in the rescue vehicle (411), a setting difficult to study using direct observation. Observation was also used to study the actions of the fire crew on the incident location. The researcher was not sitting in the rescue vehicle (411), where all the communication took place, but positioned on the ladder vehicle (413) also dispatched to the incident. Being unable to do direct observations in the rescue vehicle (411) and only rely on video data has its shortcoming. However, the phenomena under study were sensemaking, an activity typically visible in conversations. The conversation over radio and in rescue vehicle (411) was captured on the video recording. The dual use of data collection methods has provided complementary data for the analysis. Observation has provided contextual data and general understanding of the work domain whereas the video data has provided means to perform micro analysis of the work practice. The observations provided the fundament for the narrow and detailed study of the video data (Heath, C. & Hindmarsh, J. 2002). The specific incident was selected from a collection of incidents and the purpose was to show how a fire crew is making sense of an incident during enroute.

The theory of sensemaking was applied as an analytical lens showing how initial and vague information influences the actors following actions and understanding of the situation. In the chain of interaction it was evident that commitment binds the actors to their actions. Further the findings show how committed actions and their consequences are complicated to reverse.

The design implications was derived from the data suggesting functionality to improving the sensemaking process by supporting the issues of *knowing where* and *knowing what*. The suggested functionality aims to provide richer information and listen-in support that improve the collaboration support between the IC, fire crew and the command centre. These design implications have consequences for the organization both on a technical level and on a role level. The consequences on a technical level involve a re-design of the information technology and systems of the fire and rescue services. Portions of the geographical information systems currently existing only at the command centre must be deployed in rescue vehicle setting. Additional data sources partly providing the contextual information requires the fire and rescue services to provide interfaces for external providers of sensory data. The voice-communication infrastructure must provide transparent access to a variety of communication channels such as radio-, mobile phone-, and fixed telephone-traffic.

The organizational consequences with improved collaborative support will have consequences on role specific tasks. Providing the fire crew access to incident information during enroute will change their relation to the IC currently mediating such information. The hierarchical chain-of-command has to be adapted to the suggested changes in how information is delivered. Over time the work in the command centre could due to information technology improvements potentially change from a command and control function to resemble more to an information broker service. Understanding that the preferential right of interpretation in this practice resides on the operative fire crew and not the CCO as the centralized coordinator opens up questions regarding how time critical information should be retrieved and delivered. Further, the role of the coordinator and the organizational position and mandate for this role is not unproblematic. Changing the roles and work practice will not be done in short time nor is it an objective. But changes in information technology will inevitably also affect the structures in the command centre and the CCO role in providing support to IC.

8 Conclusions

In this paper an analysis of sensemaking in a fire crew enroute to an incident has been presented based on the theory of sensemaking. Empirical data from one incident has been analyzed in detail resulting in implications for design. These implications consist of functionality to support the

use of contextual information, direct access to first hand information, and improved collaborative functionality between the command centre operators and the fire crew. The consequences of the suggested information technology improvements have been briefly elaborated. However, what the exact consequences will be and the effect it will have on structure, roles, and responsibilities are severely hard to foresee. Therefore, all information technology design in this domain must be done with reflection and be driven by a clear objective to enhance the ability of the actors and not driven from a technology perspective.

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References

Burke, E. & Hendry, C. 1997. Decision making on the London incident ground: an exploratory study. *Journal of Managerial Psychology*, 12(1): 40 -- p47.

Dunn, J. C., Lewandowsky, S., & Kirsner, K. 2002. Dynamics of communication in emergency management. *Applied Cognitive Psycology*, Volume 16(Issue 6): 719-737.

Hammersley, M. & Atkinson, P. 1995. *Ethnography* (second ed.). London: Routledge.

Hughes, J., King, V., Rodden, T., & Andersson, H. 1995. "The role of ethnography in interactive systems design". *Interactions*, 2(2): 56-65. ACM Press, New York, United States.

Klein, G., Calderwood, R., & Clinton-Cirocco. 1988. *Rapid decision making on the fire ground: 108*. Alexandria: Klein and Associates Inc, U.S Army Research Institute for the behavioural and social sciences.

Heath, C. and J. Hindmarsh. 2002. *Analysing Interaction: Video, ethnography and situated conduct*. In May, T. (ed.) Qualitative Research in Action. London: Sage.

Mendoca, D., Beroggi, G. E. G., & Wallace, W. A. 2001. Decision support for improvisation during emergency response operations. *International Journal of Emergency Management,* 1(1).

Perrow, C. 1984. *Normal accidents.* New York: Basic Books.

Pink, S. 2002. *Doing Visual Ethnography*. London: SAGE Publications Ltd.

Weick, K. E. 1988. Enacted sensemaking in crisis situations. *Journal of Management Studies*, 25(4): 305-318.

Weick, K. E. 1993. The collapse of sensemaking in organizations: The Mann Gulch disaster. *Administrative Science Quarterly*, 38(4): 25.

Weick, K. E. 2001. *Making sense of the organisation.* Malden, Massachusetts: Blackwell Publishers Inc.

Weilenmann, A. 2003. *Doing Mobility,* Doctoral dissertation, Gothenburg University, Gothenburg

Paper 2

Shared use of information technology in emergency response work: Results from a field experiment

Jonas Landgren

Abstract

This paper presents results from a field experiment of IT-use in emergency response work of a fire crew. A prototype has been developed to probe for instances of sensemaking supported by IT-use in such work. The findings have been analyzed in relation to research on design of emergency management information systems and sensemaking theory. Key findings from the field experiment suggest that there is a potential conflict between the role-based emergency management information systems and the shared use of information technology of first responders. Further it is advocated that prototypes should be used to explore the extrinsic of the work practice difficult to uncover using only direct-observation or interviews.

Keywords

Field experiment, Technology use and design, Sensemaking, Emergency response work.

1 Introduction

Major efforts are now being made to design various emergency management information systems that can support and improve the work on organizational levels, inter-organizational level, national levels and even global levels in case of emergencies or crisis. Independently of the scale of the emergencies or crisis the systems aim to provide improved overview of the situation and to provide ability to make competent actions in order to take control over the situation and minimize the damages to people, property and the environment. In order to accomplish such ability, information systems must both provide support for high-level coordination as well as support for the time-critical work by first responders.

A substantial body of knowledge has been established concerning the crisis phenomena (Perrow, 1984), organizational structures for emergency management (Bigley and Roberts, 2001) and the social dynamics in emergencies (Weick, 1993). In a complex society where a small accident quickly can develop into a major crisis, emergency management is no longer only of local concern but requires the efforts of several organizations to manage. Information technology is therefore fundamental in the emergency management system to mediate intra and inter-organizational communication and collaboration. Studies of information technology in an emergency management and incident response setting includes; studies of information technology as an organizing resource (Calloway and Keen, 1996), key functionality in emergency management information systems (Turoff, Chumer, Van de Walle and Yao, 2004) and information technology in relation to coordination complexity. These studies provide high-level conceptual frameworks that could be used to inform the design of information technology for emergency management.

The operative field personnel, physically responding to an emergency, have traditionally only gained limited attention. However, there are studies that have explored how to design of information technology use for field settings such as, how to improve radio communication on the fire ground (Camp, Hudson, Keldorph, Lewis and Mynatt, 2000) how ubiquitous computing could improve accountability and awareness for the fire crew (Jiang, Hong, Takayama and Landay, 2004). In these studies, interviews and observation has been the primary means for informing the design of prototypes and workshop sessions has been used to evaluate the prototypes.

There is a gap between studies of high-level design of information systems for emergency management and the applied use of information technology by first responders. Few studies have focused on how the operative use of information technology at an accident site will affect the high-level system and vice versa. Among the few is a study that explores the use of handheld computers and the design of location based service for medical first responders in relation to the somatic health-care processes (Togt, Beinat and Scholten, 2004).

If we are truly interested in understanding how to design information systems for crisis and emergency management we need to put our designs virtually in the hands of the people that we are attempting to support.

This paper presents results from a field experiment where a mobile application prototype has been used to probe for instances of sensemaking in emergency response work of a fire crew. In addition to the findings regarding the use of information technology for sensemaking, it is advocated here that field experiments are not only valuable to explore the suggested design but also to explore additional dimensions of technology use in this work domain impossible to uncover without a field experiment. The findings from the field experiment present consequences for the design of emergency management information systems.

The argumentation builds on two strands of related research, (i) structures for emergency management and (ii) information systems for emergency management. Designing information systems for crisis and emergency management is a daunting task. Part of the problem is related to the uncertainty and the dynamics of the emergency. To avoid developing structures that are too situation specific more loosely structures have been proposed, that have a certain degree of structure yet flexible to be adapted to the specific emergency. Bigley et al (2001) reports of one such structure, namely the incident command structure employed in modified forms by several fire and rescue services. One of the major strengths of this structure is its ability to both provide flexibility and structure at the same time. A crucial aspect in this ability is the concept of role switching, meaning that people in this structure can move between different roles depending on progression of the physical emergency. The concept of roles is also important to consider when designing information systems for this work domain. Turoff et al (2004) propose functionality of emergency management information systems where it is suggested that roles plays a key part of any structured group communication process. With the assigned role for a particular individual, being part of the emergency response work, a specific responsibility and access to the system is granted. Further it is suggested that the content of the information in such system determines which roles could access the information. In order to mediate information from the emergency management information system to the people on the incident location responding to the emergency, various forms of mobile information technology is needed. Turoff et al (2004) explains that their suggested system relies on the availability of PDAs, mobile phones, and laptops but a limitation factor is how to accommodate for limited screen sizes and various interaction modalities.

However, assuming that all individuals involved in emergency response work have access to mobile information technology could present some problems. If the role is determining what information can be accessed then a shared use of the mobile technology could restrict the information technologies potential. Assuming a private or role specific use of the mobile technology conflicts with the work practice of how tools, material and possibly information technology is used on the accident location. This paper will present such collaborative and shared use by presenting findings from a field experiment that aimed to probe for instances of sensemaking supported by IT-use in a fire crew's emergency response work.

2 Theory

The theory of sensemaking is applied in this paper to provide a lens through which the actions of the fire crew can be understood. Sensemaking is an individual and collective process where "reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs." (Weick, 1993). This means that in contrast to decision making where the key question is *what shall we do*, in sensemaking the key question is: *what is going on*. A fundamental aspect in sensemaking is to understand that a person or a collective's experiences of a situation are progressively clarified, and that this clarification often works in reverse (Weick, 1995). In order for people to make sense, they must act, since it from a sensemaking perspective is understood that action precedes understanding. People actively interact to create meaning by the enlargement of small

cues. The social context in which sense making takes place affect what cues will be extracted and how these cues are interpreted as well as the revision of those interpretations based on following actions and their consequences. The making of sense is oriented towards the plausible rather than the accurate due to the time criticality in many situations. Situations colored by ambiguity or unexpected events make visible people's efforts to make sense.

3 Method

This section presents the method used to conduct the field experiment. First, the prototype design process is outlined. Second, the field experiment is presented and third the data collection and analysis methods of the collected data are explained.

3.1 Participatory design of a prototype

The prototype is designed based on findings from on extensive ethnographic field study (Hammersley and Atkinson, 1995) showing how sensemaking (Weick, 1995) plays an important role in fire crews work en route to an accident (Landgren, 2004). The prototype was designed to materialize a subset of the findings from the field study. The prototype was developed to probe for instances of sensemaking of a fire crew en route to an accident and to improve their actions on the accident location. The development process was characterized by participatory design (Blomberg, Giacomi, Mosher and Swenton-Wall, 1993) where a fire crew has been deeply involved in the process to achieve a relevant transformation from the identified design implications to the materialization of the prototype. This approach shares some ideological beliefs with the use of cultural probes where the probe or in this case the prototype *"helps the designer to learn about the local culture in order to avoid the design to be irrelevant or arrogant"* (Gaver, Dunne and Pacenti, 1999). As a result of the hierarchical command structure in the fire and rescue service, the intended user of the system was the incident commander but the content of the prototype was designed with the incident commander and the fire crew. Prior to the field experiment minor tests had been performed regarding the user interface and the interaction design. This was accomplished in a classroom setting at the fire station with the incident commander and the fire crew.

3.2 Field experiment

To probe for instances of sensemaking supported by IT-use and more practically, to explore the use of the prototype in as natural setting as possible, an incident scenario was constructed. The scenario was then performed as an exercise-incident having the fire crew responding on a reality-like emergency. The aim of the scenario and the incident-exercise was to provide a setting where the researcher to some extent could have control over some of the variables. A field experiment is not the same as an experiment in a laboratory setting, it is much more unpredictable and basically is it a semi-controlled context where initial design suggestions can be studied and potential design alterations can emerge.

3.3 Data collection and Analysis

To collect as rich information as possible, both non-participatory direct observation and video recording was used. A video camera was mounted in the rescue vehicle to capture the work en route to the accident location. The author was on the "accident" location and when the fire crew arrived, followed the prototype in the different use situations that emerged. A second camera was used on the accident location to record the use situations. Following the technology is a viable approach when studying mobile technology use (Weilenmann, 2003).

The data collected from the field experiment consisted of field notes and video recordings which were transcribed. In the work of analyzing the field notes, categories was formed and themes where derived. The analysis of the video recording was inspired by interaction analysis (Heath and Hindmarsh, 2002) and includes a detailed analysis of micro-events when a user is interacting with an artifact as well as managing the ongoing conversation with co-located individuals.

4 The prototype

The prototype named Rescuelab, aims to target the needs of timely and relevant information in incident response work. Fundamental requirements in such work have been reported of in Landgren (2004) and are access to information describing the incident location with contextual information. Based on these high level requirements the prototype was developed consisting of two main components: *an interactive map* of the city and *specific property information* linked to the position of specific risk objects.

The interactive map is basically a street map with functionality to zoom and scroll. Depending on the zoom level additional layers of contextual information becomes visible such as building borders, aerial-photos of buildings, fire hydrants, recreation areas, industrial areas and so forth. *Specific property information*, consist of a set of information for each particular property such as a hospital, a school, a factory, a shopping mall. Each property is described by a schematic map, showing preplanned intervention routes, hazards, ventilation shafts and other contextual details. For some of the properties building blueprints are available. Aerial-photos are available for all properties.

Interaction with the prototype is done via the touch screen no hardware buttons are used. The prototype runs on a rugged tabletpc with a weight of 2 kilograms. Macromedia flash and html has been used to develop the user interface. Map-functionality is provided using a commercial GIS-software.

4.1 The field experiment scenario

The following scenario information is presented to give the reader an indication of what type of exercise incident the fire crew were dispatch to.

The exercise incident was based on a scenario where a person calling the SOS 112 explaining that; while sitting in the kitchen seeing through the window some smoke at the facade of the nearby factory. The caller is unable to see any flames and is unsure if there is a fire but feels required to contact the SOS 112. The operator sends an alarm to the local fire station, dispatching them with the following incident description *"Investigation potential fire at, Blinksfactory, Mortarstreet 17"*. En route to the factory location, the incident commander (IC) contacts the command centre. The command centre operator provides some additional information; *"The caller says he has seen some smoke from the facade of the factory, ...he calls from Landstrikestreet ... it was difficult to get anything else"*. The IC response *"okay...we will have a look when we arrive, over"*.

When the fire crew arrived to the incident location, witnesses near the factory premises informed one of the firemen that they had seen a person on the factory roof. The fireman receiving this information contacted immediately the incident commander about this report.

The scenario was constructed to include situations with ambiguity which potentially would provide instances of sensemaking and where the use of the prototype could support the ongoing work. The scenario was constructed based on more than 800 hours of field studies of operative fire crew work, and therefore based on situations that the fire crew had been experiencing.

5 Findings

In this section findings from the field experiment will be presented. Two instances of sensemaking supported by IT-use will be presented in the following two subsections showing how the prototype supported the incident commander and the fire crew in their efforts to make sense of the incident and to form appropriate actions. In the third subsection additional findings will be outlined from the field experiment regarding the collaborative and shared use of the prototype.

5.1 Supporting enroute sensemaking

The first instance of sensemaking supported by IT-use concerns the work that is done by the fire crew enroute to the incident location. The use of the prototype en route to the incident location was focused on determining the plausible location of the potential threat to the factory, namely the façade where smoke where visible according to the caller. As presented in Landgren (2004) the use of reference points are important in order to make sense of an incident location. The following excerpt from the recorded information illustrates a conversation in the rescue vehicle concerning how to make sense of the plausible incident location at the factory premises.

IC = Incident commander, DRIVER = driver of the vehicle,
FM = Fire Crew Foreman

> 01: IC: If one looks from the Landstrikestreet, then it should be some where here (pointing on the screen).
>
> 02: IC: Take it [the tabletpc] (The IC hands over the artifact to the fire crew foreman and the two firemen in the backseat compartment).
>
> 03: DRIVER: It's the back of the factory you see from up there.
>
> 04: IC: Yes, any other side of the factory is not visible to him [the alarm-caller].
>
> 05: FM: There is, up there...is the Landstrikestreet (leaning forward showing the screen).
>
> 06: IC: Huhum (the IC turns round and looks at the screen).
>
> 07: FM: Hmmm...on the back....

Sitting in the front seat next to the driver, the IC holds the prototype with the left hand while at the same time interacting with the prototype using the right hand on the touch screen. The IC talks to the fire crew and express his understanding of which side of the factory one could possibly view from the position of the caller (01). The IC is using reference points to triangulate a plausible location to proceed to on the factory premises. Following to this, the prototype is handed over to the firemen in the backseat (02). The driver contributes to the conversation (03) and the IC emphasizes the position of the plausible location. In the backseat the fire crew foreman (FM) starts to interact with the prototype and engage the IC in the front seat in a new triangulation effort (05). The IC turns his head and looks on the screen and confirms (06). The FM says quietly "hmmm...on the backside" (07).

In the above excerpt it is shown how the location maps provide material for sensemaking by improving the ability of using reference points to determine the plausible location of the incident location. The location maps provide cues to the people in the vehicle and based on their prior knowledge about the factory surroundings, a commitment of where to proceed on the premises is formed.

5.2 Supporting sensemaking to form appropriate actions

The second instance of sensemaking supported by IT-use concerns the work on the incident location in the efforts to form appropriate actions. The prototype is not only used en route to the incident location but also to make sense of appropriate actions on the incident location. In the following excerpt it is shown how the prototype is used as an artifact to make sense and form appropriate actions. In the initial sequence a fireman and the fire crew foreman (FM) is using the prototype to locate their current position on the schematic building maps.

Prior to the following conversation the incident commander and the fire crew have been informed that witnesses near the factory premises have seen a person on the factory roof.

IC = Incident commander, FM = Fire crew foreman

> 10: FIREMAN: That would be this one...We are here, huh?
>
> 11: FM: Yes.
>
> 12: FM: One could go round here ...up here, from the opposite side...one can go through to this section.

The incident commander (IC) walks up to them, expressing a concern regarding what building section is connected to the main roof of the building.

> 13: IC: I don´t know if it is connected to those ladders on the roof. Bill is up there right now... the question is if should take the extendable ladder and go up on the roof just behind us.
>
> 14: FM: If you see here it looks as if it is a bypass there. (pointing his finger on a bypass on the schematic building map).
>
> 15: IC: Yes.
>
> 16: FM: That´s a separate building (pointing on the screen).
>
> 17: IC: And you mean that we should go up here, slant across from here (pointing with his hand across his shoulder)....take the extendable ladder it is only three meters [high].
>
> 18: FIREMAN: Okay.

What is show in the excerpt above is how the IC interrupts the FM and fireman in their discussion of the location and expresses a concern regarding which building section to use in order to bring additional people up on the roof (13). The FM uses the prototype to show contextual restrictions on the premise (14). The FM continues to explain that the nearby building section actually is a separate building, not visible from their current position (16). The IC expresses an interpretation of the FM's intention and forms appropriate action (17). The fireman standing next to the IC and FM agrees to that action (18).

The confusion regarding which building section is connected to the main roof was managed by face-to-face interaction between the FM and the IC. Rich media mediated by the prototype provided multiple cues. These cues were used by the IC to form the appropriate action and to get commitment to that action.

5.3 Collaborative and shared use

As shown in above subsections, emergency response work is a collaborative activity where sensemaking is fundamental. In this subsection additional findings from the field experiment will be presented showing collaborative and shared use of the prototype.

Before outlining this issue, let's briefly present the information technology currently in use in some fire and rescue services in Sweden. Information technology currently in operative use is designed to provide similar functionality as the prototype used in the field experiment. But, a fundamental difference between the prototype and the existing technology use available for operative rescue services in Sweden, is the stationary design. The information technology currently in use is mounted in rescue vehicles restricting it from a mobile use. In the field experiment it was shown how the mobile technology manifested in the prototype can and will be used by different roles in the fire crew and in a variety of settings. During the exercise the prototype was not only used by the IC alone or by the IC in collaboration with another role, but also by roles independently or in collaboration with other roles.

At a few occasions during the field experiment, the IC handed over the device to either the fire crew foreman or a fireman. One such hand-over occurred in the vehicle en route to the accident location, While en route to the accident location, one of the firemen in the ladder vehicle (413) contacted the IC in the rescue vehicle (411) and asked for positions regarding the location of fire hydrants. The following sequence illustrates potential problem of who is actually using the device and where such use takes place.

IC = Incident commander

> **30: Fireman in vehicle 413:** 413, 411.
>
> **31: IC:** Over.
>
> **32: Fireman in vehicle 413:** Just want to check if you have found any water, to help us a bit.
>
> **33:** Just a moment...eh it [the device] is in the backseat right now so we have to call back.
>
> **34: Fireman in vehicle 413:** Okay.
>
> **35: IC:** You contact 413, jonathan [referring to the fireman holding the device].
>
> **36: Fireman in the backseat of 411:** Yes.

The fireman asking for assistance in locating fire hydrants contacted the rescue vehicle 411 over the common en route radio channel. This channel is open during en route and used for communication between the command center and all vehicles en route to an accident, as well as between vehicles. The incident commander is responsible for handling such radio traffic in rescue vehicle 411. The radio is positioned next to the IC´s seat. The IC had prior to this call for assistance handed over the prototype to the firemen in the backseat, making a respond to the request impossible. The IC handles the situation by asking to call back in a moment and asking a fireman (Jonathan) in the backseat to search for the information and contact the ladder vehicle 413. This situation shows how the prototype is used as a common resource for the fire crew in the rescue vehicle and indirectly by firemen members of the fire crew located in other vehicles. The hand over situations and the unconstrained access to the prototype shows that the technology is shared within the group and is potentially perceived as a common resource.

6 Discussion

In this section, the findings presented in this paper will be discussed. There are three issues that will be elaborated; instances of sensemaking supported by IT-use, technology in a collaborative practice and finally some reflections of the use of field experiments and prototypes will be presented.

6.1 Technology to support sensemaking

Sensemaking is based on the assumption that *"reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs."* (Weick, 1993). The job for the person trying to make sense of a situation is to convert experiences to something meaningful and this is highly dependent on the social context. Situations are progressively unfolding and clarified and this clarification emerges when people in retrospect brings the pieces together to create a sensible explanation of the situation. As shown in the findings to make sense, people as actors in a social context will interact and make committed actions based on cues that help them to justify their actions in that particular social context. Findings from the field experiment show instances of sensemaking where location specific information mediated by information technology can improve the fire crew's sensemaking ability. This claim is supported by the observation of how the information provided by the prototype was used in the conversation between the individuals in the social context of the fire crew. Further, the cues extracted based on the information presented in the prototype formed commitment for those actions. As mentioned, sensemaking is a social activity and as such the material provided to make sense is also part and forms that social context. As shown in the findings, making sense is a social activity and a collaborative effort. This is vital to understand when the artifacts used for sensemaking will be discussed next.

6.2 Technology in a collaborative practice

Information technology mediating vital information is, whether or not the intended user is a specific role, part of the collaborative practice and by such also in this work domain associated with a shared use. This has implications on how to design emergency management information systems and how information technology is introduced in the incident command structure. The typical command structure is highly hierarchical and the term chain of command, clearly illustrates that information and decision is a top-down process. However if the incident response, where a sensemaking ability is critical, is a collaborative activity and the physical tools and technology artifacts are viewed as common resources then the design of information technology to support incident response must comply to the work culture and the collaborative practice. Designing information systems for specific roles and designing functionality that requires that specific role's immediate attention could conflict with the current work practice. The findings from the field experiment shows how sensemaking as a social activity is a collaborative effort and not an effort only managed by one role. A role-focused design of information technology and information systems as suggested by (Turoff et al., 2004) could potentially have severely negative effects of the ability of the first responders. This does not mean that a role-based design is inadequate but rather that we must extend our understanding for the social activities and context of a particular role and provide a design that can accommodate for a collaborative practice. If we overlook the social dimensions of collaborative work practice we might design information systems that not only are seen as inappropriate by the work force but also and more importantly, decrease the efficiency of a response operation.

6.3 Technology as a vehicle to understand work practice

The field experiment has highlighted at least one vital issue impossible to explore without actually moving out in the field and putting information technology in the hands of the work group. The field experiment was intended to probe for sensemaking supported by IT-use in a reality-like situation but did also provide an opportunity for the researcher to explore additional questions very hard to imagine before the field experiment. The prototype did provide knowledge about the practice that prior to the exercise was still unknown. A note of advice to individuals that are involved in exploring the use and design of information systems for crisis management and emergency response is to move out in the field and not only study the actual work but also to use the work setting to further explore this research field.

7 Conclusions

This paper has presented findings from a field experiment used for probing instances of sensemaking in a fire crew in emergency response work. The field experiment resulted in additional findings concerning aspects of the work practice that potentially have implications on the design of emergency management information systems. A key finding from the field experiment is that there is a potential conflict between the role-based emergency management information systems and the collaborative practice of first responders. Further it is advocated that prototypes should be used to dig deeper in the extrinsic of the work practice difficult to uncover using only direct-observation or interviews of current work practice. The intention should not always be to design prototypes that "fit" the work practice but to design prototypes that can help us gain further and more detailed knowledge of the setting.

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References

Bigley, G. A. and Roberts, K. H. (2001) The Incident Command System: High-Reliability Organizing For Complex and Volatile Task Environments, *Academy of Management Journal*, 44, 1281-1300.

Blomberg, J., Giacomi, J., Mosher, A. and Swenton-Wall, P. (1993) In *Participatory Design: Principle and Practic* (Ed, Namioka, A.) Lawrence Erlbaum Associates Publishers, Hillsdale, New Jersey.

Calloway, L. J. and Keen, P. G. W. (1996) Organizing for crisis response, *Journal of Information Technology*, 11, 13-27.

Camp, P. J., Hudson, J. M., Keldorph, R. B., Lewis, S. and Mynatt, E. D. (2000) In *Conference on Human Factors in Computing Systems*ACM Press, New York, NY, USA, The Hague, The Netherlands, pp. 249-250.

Gaver, B., Dunne, T. and Pacenti, E. (1999) In *Interactions* (ACM), Vol. 6, pp. 21-29.

Hammersley, M. and Atkinson, P. (1995) *Ethnography*, Routledge, London.

Heath, C. and Hindmarsh, J. (2002) In *Qualitative Research in Action* (Ed, May, T.) Sage, London, pp. 99-121.

Jiang, X., Hong, J. I., Takayama, L. A. and Landay, J. A. (2004) In *2004 conference on Human factors in computing systems*ACM Press New York, NY, USA, Vienna, Austria, pp. 679 - 686.

Landgren, J. (2004) Fire Crew Enroute Sensemaking, In the proceedings of International Workshop on Information systems for Crisis response and management, (Ed, Walle, B. V. d.) Brussels, Belgium.

Perrow, C. (1984) *Normal accidents*, Basic Books, New York.

Togt, R. v. d., Beinat, E. and Scholten, H. (2004) In *First International ISCRAM Conference*(Ed, Walle, B. V. d.) Brussels, Belgium.

Turoff, M., Chumer, M., Van de Walle, B. and Yao, X. (2004) The Design of Emergency Response Management Information Systems, *Submitted to JITTA for publication* 2003-05-09.

Weick, K. E. (1993) The collapse of sensemaking in organizations: The Mann Gulch disaster, *Administrative Science Quarterly*, 38, 25.

Weick, K. E. (1995) *Sensemaking in organisations*, SAGE Publications Inc, Thousand Oaks.

Weilenmann, A. (2003) *Doing Mobility*, Gothenburg University, Gothenburg.

Paper 3

Making action visible in time-critical work

Jonas Landgren

Abstract

This paper presents descriptive accounts from an ethnographic study of time-critical work in the domain of emergency response and the operative work of fire crews. The verbal communication as part of such work creates difficulties in providing accountability of the fire crew's actions. The concept of work rhythms and temporal structures is used as an analytical framework. Design implications are presented suggesting that verbal communication should be made persistent, visible and accessible in order to support accountability. These design implications are discussed in relation to the fire crew's work practice.

Keywords

Ethnography, Time-critical work, Emergency response

1 Introduction

In a range of professions, people experience periods of severe work intensity due to a work context where time-criticality and timing are key factors for success. This is typically the case in control room work such as traffic controlling [10, 3], emergency dispatch [16] and network troubleshooting [22]. For all these settings the notion of time-critical work captures a core aspect. Time and timing are important and failing to comply is often related to fatal consequences. In these settings it is not only important to make competent and timely actions but also to document the actions in order to coordinate the work and to provide accountability of the actions taken.

In such settings, computer-supported collaborative work (CSCW) applications have an important and central role by providing shared visual representations to promote collaboration between distributed actors.

However, severe work intensity and time-criticality are not exclusive for control-room settings but also an unavoidable part in field-work settings of mobile professionals such as for service technicians [6], police patrols [14] and firemen [13]. In these non-office work settings collaboration is accomplished using other means than traditional CSCW-applications. Studies of people engaged in physical tasks and physical collaboration have shown that speech is the primary mean for coordination [7]. Verbal communication is beneficial for coordination but implies a distinct problem regarding accountability.

This paper reports from a study of time-critical work in the domain of emergency response, with a focus on emergency response work performed by firemen. In emergency response work, documentation of actions taken as part of an incident has become increasingly important but very problematic due to the absence of appropriate support. Traditionally, documentation has been an activity that primarily takes place after the physical emergency response operation has been completed and the fire crew is back at the fire station. This is about to rapidly change. There is now a strong movement in the emergency management community enforced partly by new *national accident prevention legislation* and partly by a general awareness that documentation of vital events and actions could provide insightful material for analysis and improvements of the work practice. Attempts have been made to explore the use of handheld

devices for documentation of important actions during response work. The results of such efforts have been poor. Managing documentation activities during response work has conflicted with the physical work to handle the emergency.

The research question addressed in this paper is: How can accountability be provided in a time-critical work practice where verbal communication is the primary mean for coordination?

2 Related work

There are several reasons to the unsuccessful attempts to provide information technology support for documentation as part of emergency response work. Not surprising, the problems are related to inadequate technology design in relation to the pre-existing work practice. These problems will be discussed in relation to related work.

First, a major problem is the focus to provide information technology designed to fulfill the needs of a paper based practice. Studies of time-critical work have shown that textual information is not necessarily the obvious means by which people coordinate their work. Instead, for some work practices the primary means of coordination is speech [19, 22]. Studies of communication patterns in emergency response work support this view showing that ambiguous situations result in an increase of spoken communication [5]. User-centered studies of fire crew radio-communication [4] have shown the need for improvements regarding radio communication functionality.

Second, the aim of the documentation is understood to focus on capturing explicit decisions and important events as part of the work on the accident site. In emergency response work of fire crews, decisions are not explicit, but intertwined in the conversations and the situated actions. Firemen rarely reflect on several decision alternatives but rather use a single option strategy [11]. Sensemaking and not decision making is the issue that is central to the fire crew work in emergency response. Analysis of break-downs in sense-making [20] and studies of how information technology can support fire crews in emergency response work [13] show how the effort to make sense is central in operative emergency response. Sensemaking as defined by Karl Weick is as an individual and collective process where *"reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs."* [20]. This is contrasted to decision making where the question is what shall we do, whereas in sensemaking the question focuses on what is going on. A fundamental aspect in sensemaking is to understand that a person or a collective's experiences of a situation are progressively clarified, and that this clarification works in reverse [21]. In emergency response, the situation which the fire crew responds to is many times unclear or ambiguous. In order to make sense, people must act since, from a sensemaking perspective, it is understood that action precedes understanding. People actively interact to create meaning by the enlargement of small cues and forming a structure to provide meaning. A fire crew cannot wait to respond or postpone their actions, even when the situation is equivocal. They must act even when the risks are severe, which was brutally evident in the 9/11 World-Trade Centre disaster.

Third, time-criticality and rapidly changing situations limit the ability and priority to type in information to provide documentation. The need to make physical actions takes precedence over what is understood as less important work. Further, studies of service technicians have shown how users struggle to align the mobile computers with the work situation at hand due to interaction issues. Making place [12] for IT has become an extraneous activity to adapt the situation to the abilities of the mobile technology. In other studies [6], embodied interaction has been adopted to guide the design of mobile technology for service technicians in order to avoid such problems.

In the next section, work rhythms and the notion of temporal structures will be adopted as an analytical framework to illustrate aspects of time-critical emergency response work.

3 Analytical framework

The Time has gained renewed attention in organizational studies and in IS-research. Recent studies suggest that time provides a new and complementary lens [1] to the existing strategic design, political and cultural lenses used to explore how organizations function. They claim that a primary benefit of applying a temporal lens is that it allows us to explore

not just processes and practices but the pace by which they move, the trajectory over time and what they align with.

Wanda Orlikowski and JoAnne Yates present the concept of temporal structuring to show how people experience time through the shared temporal structures they enact continuously in their everyday practice. People produce and reproduce a range of temporal structures which shape the temporal rhythm of their ongoing actions. Further, a practice-based perspective is applied that is suggested to overcome the traditional dichotomies that earlier researchers have used to discuss time, such as the dichotomy between subjective vs. objective conception of time [15].

From an IS-perspective, Madhu Reddy and Paul Dourish have made studies of temporal rhythms and information seeking in medical work [17]. They propose that information seeking should not be viewed as a separate task from other work activities. Instead they suggest that information seeking must be understood as an integrated activity in the everyday work of medical workers. By outlining large-scale and fine-grain temporal structures in the everyday work they illustrate how information seeking is a seamless and interwoven part of the everyday work and by that shape and is shaped by the work rhythms. This means that people create temporal structures as means to accomplish their work; project deadlines, meeting schedules and even lunch breaks can be seen as temporal structures. When people create temporal structures, they become also dependent on them. They shape their own work in relation to the temporal structure, such as working overtime to meet a deadline, or by re-scheduling a deadline.

In this paper, the concept of work rhythms and temporal structures will be adopted to give a contextual view of the rhythms and temporal structure in emergency response work. The concept of large-scale has been applied here to identify and present the large-scale rhythms of emergency response and related temporal structures.

4 Method and research setting

This study is part of an action-research project [1] focusing on the design of information technology use in supporting emergency response work of fire crews in communal fire and rescue services. An extensive field study, started in 2002, has been conducted using an ethnographically inspired approach [9] with approximately 800 hours of participant observations. The observations have taken place as part of the fire crews' normal work shifts including 10-hour day shifts, 14-hour night shifts and 24 hour weekend shifts. In order to study emergency response work using a participant observation approach, also non-emergency work has been covered in this study. Emergencies are not easily scheduled which has resulted in an ongoing prolonged field study. On incidents, the author has been using the mandatory protective jacket, pants, boots and helmet.

The rich and large amount of material from the field study is used for providing a deep understanding of the work practice in order to inform the design of information technology use.

The data presented in this paper is from one incident but analyzed in relation to material of the entire study. The data consists of transcribed field notes written down during the response work as well as after an incident. Fire crew radio-communication on the incident location has been recorded using an mp3-player taped on the handheld radio. Radio-communication during transportation has been recorded via the vehicle communication-radio. The recordings have been transcribed and analyzed. Interviews have been made with fire crews for the purpose of capturing their reflections of recent incidents and their reflections on how they experience aspects of the time-critical work.

The setting reported of in this paper is operative emergency response work in communal fire and rescue services in Sweden. Fundamental characteristics of emergency response work is the uncertainty of what a fire crew will face on arrival to the accident location, the ambiguity resulting from incomplete or incorrect information from the alarm-caller, and the urgent actions that need to be done by the fire crew that are both unable to postpone and irrevocable when made. The physical work of emergency response is performed by fire crews. A fire crew consists of one fire crew commander (FCC) and four to six firemen. The fire crew commander takes the role as incident commander (IC) when the crew is dispatched to an emergency. When additional fire crews are dispatched to the same incident, a new commanding level is also dispatched and the role of incident command is switched to this new level. Incident dispatch is triggered by SOS-112 alarm-call and managed by command centre operators (CCO) located in a central command centre.

4.1 Retrospective documentation practice

Prior to presenting the work rhythms and temporal structures in emergency response work, the current retrospective documentation practice will be outlined. Documentation of emergency response work is a retrospective activity accomplished at the fire station after the emergency response operation. It is retrospective in the sense that the documentation outlined in an incident report is based on the reflections of a completed operation, based on the memories of the incident commander and brief notes scribbled down in note books, and in hindsight with the knowledge of the result of the operation. To a varied degree and depending on the organizational norms, some incident commanders make brief notes of important events and actions using pen and paper. Progressively and slowly, the documentation practice has evolved to include alsospecific time-stamped events generated and logged by the command center's computerized dispatch system. A range of time-stamped events have been added to the documentation and includes, time at the dispatch event, turn-out time, time at arrival, time at intervention and the time when the response work was completed. On the basis of all these time structures, lead-times are calculated. The incident documentation is performed using a computerized incident report software where the incident commander type-in the accounts and reflections of the incident. The incident documentation includes both qualitative (retrospective accounts) and quantitative information (time-stamped events). When completed, the documentation is submitted to the national Rescue Agency for statistical analysis.

5 Results

In this section results from participant observation of an actual incident are used, in combination with excerpts of transcribed radio communication from the same incident. In addition to this, also data from interviews with fire crew commanders and firemen is used to provide a rich illustration of the work practice.

In emergency response work, one can broadly speak of three sequential and distinct large scale rhythms. The initial rhythm is the mobilization rhythm where the fire crew receives the alarm and is dispatched to the accident location. The second rhythm is the intervention rhythm starting when the fire crew arrives to the accident site and starts their physical intervention. Following to this is the situational adjustment rhythm where the fire crew's initial work has had some effect on the emergency. In the following subsections aspects in these three large-scale rhythms will be outlined.

5.1 Mobilization

The initial rhythm in emergency response work is caused by the triggering of an alarm. This rhythm has two major temporal structures; awakening and transportation, and is characterized by the sudden interruption of the ongoing activities and switch of attention to the preparations for the emergency response work that in short time will be accomplished.

> "Station B. Major Alarm. Automatic fire-alarm at the Carl-Johan School, Admiral street seventeen."

5.1.1 Awakening

The distinct sound from the fire station alarm speakers creates an immediate interruption of the current ongoing activity. The fire crew experiences a sense of awakening where the sudden alarm is forcing them to switch focus, listen to the crackling sound when the operator's voice informs about the type of alarm and street address.

> "When the alarm is sounded there is directly a sort of increased level of adrenaline or at least an awakening time where you wake up from you current activity, an interruption of what you do, and you are trying to listen to what the alarm is about." (Fireman)

While the voice informs about the alarm, the firemen proceed rapidly to the protective gears and rescue vehicles in the ground-floor garage. On their way to the ground-floor the fire crew speaks rapidly in short sentences clarifying the address and the driving directions to the location.

> **IC:** Did he say Admiral Street seventeen or seventy?
>
> **Fireman:** Seventeen...it is on the east-end of the admiral street.

The level of intensity in this activity is strongly related to the type of alarm

and the time of day. If the alarm type is Automatic fire alarm in a nursing home in the middle of the day, then the alarm is understood as less critical compared to the same alarm three o'clock in the morning. The fire crew actions in the temporal structure of awakening are highly shaped by the 90 seconds turn-out time limit but they also shape this structure by adjusting their tempo in relation to type of alarm and time of day. In this initial moment the speed of actions and intensity of their conversations in the awakening temporal structure indicate the degree of seriousness that the fire crew assigns to a specific alarm.

5.1.2 Transportation

The rescue vehicles leave the fire station and start the transportation towards the accident location. The incident commander contacts the command centre and confirms that they are on their way. The command centre operator informs the incident commander about what is known about the accident and what additional resources at this point in time have been dispatched. Often, the words of the command centre operator are hard to hear by the firemen sitting in the backseat. The incident commander repeats the information to the fire crew. During the transportation to the accident site, the fire crew is preparing for the potential situation on arrival. The conversation in the vehicle is dependent on how much the fire crew knows about the location and the resources available to make sense of the brief and sometimes incomplete information. Suddenly the command centre operator informs:

> **CCO:** We have received a call from the school and they say that there is a fire in a hall-way of building C...you will get backup from station C and station D with rescue and ladder units.
>
> **IC:** That is acknowledged...did you say building C?
>
> **CCO:** That is correct, over.

The information from the command centre operator is not just used to determine what has happened but also an indication of the scale and seriousness of the incident. A fireman explains:

> "You try to listen to what is said to the IC over the radio, if there have been many calls about this incident. You know...you can hear the way the operator is talking to know if it is serious or not."

The time period of transportation provides the fire crew with a few minutes for preparation and making sense of what will face them upon arrival. A fire crew commander explains:

> "Even if we do no physical work, we are still sitting in a rescue vehicle that is moving at high speed in the traffic. The guys are checking their stuff. The driver has the highest intensity due to the effort of driving fast to the accident site. So even if it could look as we are doing nothing, we are experiencing the opposite. Some of the guys might know the exact location and how the location looks and based on that you try to make a mental picture, what could be expected when we arrive, how we should deal with a certain issue that is specific for the accident location. So, even if it could be very quiet, that does not imply inactivity."

Incomplete or ambiguous information from the command centre can result in a significant effort for the fire crew to make sense of the situation, enroute to an accident location. Difficulties to make sense of the accident location result in intense conversations among the fire crew and pro-longed communication with the command centre [13]. What could have been perceived as non-productive time is by the fire crew used as an important time to prepare and make sense of the accident and location. The fire crew has shaped this temporal structure to become a resource in their preparations for the response work.

5.2 Intervention

The fire crew shifts into a new rhythm when they arrive to the accident location. The characteristic of this rhythm is the shift from a state of preparing to a state of physical intervention in a set of parallel and coordinated activities. The visual impression of the accident situation and the way civilians act on the location contributes to the intensity of the intervention actions. Visual signs of emergency, such as thick black smoke-clouds, flames out of the window of a building or a severely crashed vehicle are triggering factors.

5.2.1 Window report

The arrival is a critical moment where the individual as well as collective expectations, built up during the mobilization rhythm, either will be confirmed or rejected. The alignment of the built up expectations and the accident location's visual impressions are critical in order to establish a rapid intervention. As is illustrated in the excerpt below, a deviation between the expectations and the impressions on site could significantly delay the work.

> "When you arrive, you get a confirmation on the things you've been thinking and not thinking of. If the situation is similar to what you expected then your thinking process fades, but it could also be the opposite, it does not make sense ... what the heck is this ... what should we do now? If this happens, then obviously it takes some time to know what to do." (Fire crew commander)

Based on the snap-shot visual impression of the situation a verbal report, called window report, is provided by the fire crew commander, in the role of incident commander, by radio to the command centre operator. This report is very brief and the situation does not permit any discussions or follow-up questions, just a short confirmation from the command centre that the report has been received.

> **IC:** (In vehicle F511): G400... F511 arrived... we have a fire and there is heavy smoke from the hallway... I report back later.
>
> **CCO:** F511 that is acknowledged.

This report is the first verbal formulation to the command centre that explicitly is capturing what the situation is all about, based on the understanding of a rescue services professional on site. The window report is communicated using the radio allowing other fire crews enroute the accident location to take part of the information. There can be significant differences between what a non-professional has told in the 112-SOS call and what the commander reports upon arrival. The report is therefore, even if it is a snap-shot impression, a vital moment for how the subsequent actions on the accident site and the actions at the command center will be shaped. Based on the report, additional resources can be prepared for or directly dispatch by the command centre operator.

5.2.2 Situation assessment

When the fire crew dismounts the vehicles, the commander starts a situation assessment and the firemen begin to deploy equipment according to a pre-planned routine that corresponds to the situation at hand. The situation assessment has the goal of providing fundamental understanding of the emergency in order to determine how to take control of the situation and minimize its consequences. A fire crew commander explains:

> "When you arrive, you must try to understand the scale of the accident and not only from one side of the building, you must look from several angles and that takes a time to accomplish. Because of this, we have a set of planned actions so that I do not need to tell the guys what to do but for them just to get things started. And by having them started I have also created some time for me to do the assessment."

During the situation assessment task, the incident commander uses the fire crew open radio channel to inform about the situation that could require changes of the intervention tactics.

5.2.3 Rushed deployment

While the commander is conducting the situation assessment the fire crew begins the physical intervention based on a set of coordinated activities, where each activity contributes to the progression of the intervention. The pace in this work is significant. The driver of the vehicle man the pump, the breathing apparatus team (BA-team) starts to lay fire hose and locate how to get close to the fire. In case of locked doors they apply the "break-in" kit to get access. The action of breaking-in is reported back, over radio, to the commander. When the BA-team is ready to move into the hallway, they call over the radio to the pump operator that set pressure on the fire hoses.

The BA-teams' eagerness to start fire suppression as fast as possible put pressure on the pump operator to have finished the appropriate actions to provide water. The pump operator is experiencing a tight deadline. During these activities there is an intense communication over the fire crews' open radio channel, which provides awareness of the initiated work for the fire crew commander adding this to the situation assessment. A fire crew

commander explains that rushed deployment and situation assessment is highly related:

> "The orientation and assessment, well ... could be done by all of us. I have to be sharp and listen to what the other guys are saying, they see it from their perspective when they work. I have to take into account their impressions but it is then up to me to make the decision, everyone cannot make the decision...but I would be stupid if I do not listen to the guys, all this must be done in a very short time, you do not want to delay the response operation."

What is shown here is how the rushed deployment and situation assessment is not really two distinct and separate activities, but two coordinated activities that are distributed over the fire crew but ultimately being the responsibility of the incident commander. The fire crew uses the open radio channel to communicate directly to one individual or part of the group while at the same time making the conversation available to the entire fire crew.

5.2.4 Status report

The situation assessment is communicated in what is called a status report which is a verbal report with a specific structure. The status report is used for updating the command centre of the ongoing work and to allow the operator to update and prepare the arriving units. The following excerpt is from a mobile phone conversation where the incident commander is providing a status report:

> **IC:** We have a fire here in the hall-way, we have initiated extinguishing. There are some cardboards and rubbish on fire and heavy smoke. I would like to have station C prepared to initiate search and rescue.
>
> **CCO:** That is understood.

The command centre operator calls over open radio channel to inform the fire crew in the vehicles from station D about the situation and the task that they should prepare for.

The status report has several purposes. It is used for providing a current view of the situation but also to provide information that is important for the arriving units. A fire crew commander explains:

> "You try to provide the command centre with a report as fast as possible. That means that after you have retrieved a fair amount of adequate information, you want to share this knowledge with them, because they cannot see any of all this but still they must be able to provide the support I need. That is why it is important for me to deliver a picture so that they can be part of the game."

The status report is communicated over radio or mobile phone to the command centre. It provides information for the resources dispatched to the specific incident and information for possible re-allocation of available resources. The status report shapes the command center's alternatives to both assist the ongoing emergency and to provide resources for additional alarms. Allocation and re-allocation of resources are time-consuming and which makes status reporting important.

5.3 Situational adjustment

When the actions of the fire crew have started to take effect, the emergency response operation is shifting into the third rhythm. The main characteristic of this rhythm is that of situational adjustment, meaning that the incident commander is planning ahead of the development of the emergency and is adjusting the actions of the fire crew according to foreseen and unforeseen events of the emergency. Additional resources arrive at the accident location, adding the need of updating the arriving fire crew commanders and higher ranking commanders of the situation. The ambition with situational adjustment is to control and force the emergency in a desired direction. The incident commander and the fire crew commanders are here working on different time scales. The fire crew commanders work close with their fire crews and are directly involved in the physical work whereas the incident commander has provided distance, both physically and mentally, in relation to the emergency, and is focusing on keeping multiple alternatives open for any sudden changes of the progression of the response operation. This is illustrated in the following excerpt:

The unit from station C assigned to search and rescue has found

additional floor plans that are filled with smoke. They report this to the newly arrived higher ranking commander that has taken over the role as incident commander. The incident commander immediately contacts the command centre over radio.

> **IC:** We have found additional smoke on level three and four. When will station D be here, over.
>
> **CCO:** Wait a moment.
>
> **CCO:** They are arriving right now.
>
> **IC:** Good, I estimate that we will be here for the next hour, it will take some time to ventilate this building.
>
> **CCO:** That is confirmed.

5.3.1 Coordination in momentary meetings

The incident commander and the fire crew commanders are coordinating their actions using a cyclic pattern consisting of short conversations in momentary meetings. There is a continuous flow of short face-to-face meetings and radio communication embedded in the physical work at the accident site. The occurrence of these meetings is accomplished by mutual adjustment. A higher ranking commander explains:

> "These conversations happen when I need to check something or shortly discuss an issue. The meetings are accomplished in action when there is a need to talk to each other. If I see that Garry [fire crew commander] is occupied with work then I won't interrupt him. The same goes for him if he sees that I am in a discussion with property owners and a few policemen, then he will solve the issue without me."

The momentary meetings are used for coordination of actions and shaping of actions in the emergency response work. The actions are not always known in advance but are formulated as part of the work.

5.3.2 Periodic reporting

Periodic reporting to the command centre is used both as a way of continuously updating them of the current situation and to highlight any potential needs of additional resources but also as a way of moving the task of documentation of important events away from the work on the accident site. As is shown in the following excerpt, the incident commander use the periodic reports as a way to let the command centre handle the documentation of the ongoing work. A fire crew commander explains:

> "In general I rarely make any notes and instead I use the verbal reports to get something written down. I report to the command centre on what is happening...important events, so that they can add it to the protocol. And I do get disappointed if I see afterwards that they have missed certain things...but they have become better to make notes."

The incident commander has shaped the cyclic temporal structure of periodic reporting to move documentation activity away from the physical work on the accident site.

> **IC:** G400, over.
>
> **CCO:** Yes, over.
>
> **IC:** I have a representative from the school here, I will ask her to take contact with you to provide the contact info.
>
> **CCO:** Do so, over.

When the emergency is under control, the time period between the verbal reports becomes longer. It is therefore not uncommon for the command centre to take contact with the incident commander to request an update.

5.4 Incident completion

Eventually the work for the fire and rescue services is coming to an end on the incident location. This rhythm is characterized by the tasks of sending back units to the fire stations and to inform property owners of their responsibility for the premises. This rhythm consists of the following temporal structure.

5.4.1 Demobilization of units

Fire crews start to demobilize as soon as the work at the incident location comes near completion. The different fire crews are sent back to their fire stations and only a small number of firemen stay at the location. Demobilization of fire crews is a temporal structure that has significance for the command centre. From the moment of the first fire crew's demobilization, the ability to handle the next incident is increasing. It is therefore important to gradually demobilize fire crews that are considered unnecessary at the location.

5.4.2 Declaration of incident termination

When the work of the fire crews has brought the emergency to end, then this is also the moment when the responsibility of the fire and rescue services comes to an end. This clock-time is important to document and to hand over the responsibility to the property owner in a clear and formal fashion. The following excerpt shows how the declaration of incident termination is accomplished by a phone call to the command centre.

> **IC:** Okay, we will now terminate the emergency response work ...the time is sixteen thirty-four (16:34) and we hand-over the responsibility to the school representative.
>
> **CCO:** That is understood.

The command center operator documents the clock-time in the incident management system along with a note that the emergency response work is completed. The property owner is from this moment formally responsible for any further actions and the associated costs to clean-up, rebuild and prevent people to enter the damaged area.

6 Design implications

Based on the results from the study two high-level design implications have been proposed in order to answer the research question.

6.1 Make verbal communication persistent

Verbal communication has an important role for the involved actors in the accomplishment of emergency response, regardless if the actors are collocated or distributed. The verbal communication contains instances of both coordination tasks and sense making efforts. The command centre operator manually makes a few notes of what at the time was understood to be important information. It is not an exaggeration to claim that only a fraction of all the valuable information is covered by those notes.

The ephemeral aspects of verbal communication has formed a communication practice where significant amounts of information are repeated in order to transfer it between actors that are using different communication channels or communication devices. The verbal communication over radio or mobile phone is adapted to the time critical situation and consists of short sentences with a clear message.

The actions of the emergency response work are represented in the verbal communication. The actions are embedded in temporal structures which form the conversation and are thereby also represented in the communication. The work rhythm forms the conversations and makes aspects of the context of those actions visible in the conversation.

In order to provide accountability of the actor's actions in emergency response work, the design implication here is that ephemeral verbal communication must be made persistent. Making it persistent would open up for possibilities to re-call and examine sequences or the entire communication. Transforming verbal communication from a state of ephemerality to persistence means in the most practical sense that the communication sequences are recorded, tagged (time and sender id) and stored as audio-clips.

6.2 Make verbal communication visible

In initial phases of emergency response, situations are rarely fully understood. This means that emergencies are unfolding and gradually clarified by the actions taken in the three work rhythms mobilization, intervention and situational adjustment. In the mobilization rhythm the fire crew is highly dependent on information from external actors. New information during the work has significant impact on the understanding of the situation and the actions that need to be taken. Commanders engaged in the response work must focus their coordination efforts ahead of the ongoing situation.

Making the verbal communication persistent to enforce accountability will also provide means to structure and make the communication visible and accessible as part of the emergency response work. In the process of making verbal communication persistent, added meta data will provide means of organizing the clips in a structure. The simplest structure would be based on the timestamp, or aligned to the command structure based on sender id. These structures would allow new ways to make visible the work structure as a resource for sensemaking [21] as part of the ongoing work. This means that the evolving collection of verbal communication sequences would correspond to and make visible the unfolding and gradually clarifying *picture* of the emergency.

7 Discussion

In this paper, accounts of time-critical work by fire crews in emergency response have been presented showing that verbal communication plays an important role in accomplishing such work.

The study shows that explicit documentation of actions, as part of the emergency response work, is limited. This situation presents significant problems for providing documentation for accountability purposes. Findings from the study suggest that verbal communication should be made persistent, visual and accessible for the actors in emergency response.

The design implications point in the direction of a dual use of the documentation; both for the *post-emergency* work and *ongoing response* work.

In *post-emergency* work, the use of the documentation is directed on investigating the cause of the accident and evaluating the emergency response operation. The persistent communication would here be seen as a structure of digital traces of the actions and used for detailed analysis. Further, in feedback sessions the involved fire crews will be able to access the same structure of digital traces to "replay" the response work, analyze detailed communication sequences and make sense of their actions in order to both legitimize and improve their work practice. The approach of meta-tagging the collected information will allow analysis based on a specific actor or set of actors and also focus the analysis on a particular point in time. In ongoing response work, the persistent communication could be visually presented in a structure representing the involved actors, relationships between the actors, the communication intensity and the individual conversations. The structure would be accessible on the personal communication devices and used to provide cues and structure for sensemaking for the actors as part of their ongoing work.

However, making verbal communication persistent, visible and accessible would only provide minor value if the intended users have limited time to use such information. Emergency response work is time-critical and as presented in the field study characterized by temporal rhythms. The use of persistent verbal communication must therefore be aligned to these rhythms. Based on the findings from the field study, there exist occasions where such persistent verbal communication is valuable and where time is available.

One example of such an occasion is during transportation to the accident location. In current work practice, the fire crew is paying attention to the radio conversation, both to what is said and how it is said, in order to build expectations for the situation on arrival. A structure could here be valuable for units that are dispatched to an ongoing accident. Another occasion is found in the situation adjustment rhythm when the incident commander brief newly arrived resources. The documentation would here provide material for the conversation.

In relation to these occasions, there is also a potential use for fire crews and external actors that are stand-by for dispatch to the emergency to take part of the ongoing response work by having the access to the evolving documentation. Further research is required to explore how the use of the documentation can be used as part of the emergency response work practice. The next step is to develop a prototype and use it in field experiments with fire crews and incident commanders.

Providing documentation of the actions of emergency response work during the ongoing emergency will improve its value in post-emergency analysis. The argument for this is that documentation of actions should not become monitoring for post-emergency activity but a resource for sensemaking in the time-critical emergency response work. The structure of persistent verbal communication could become the shared visual representation of work for fire crews similar to what is found in successful implementations of CSCW-applications.

The suggested design implications address the major problems of emergency response documentation, outlined previously in this paper. First, the

documentation is not dependent on manual paper based note-taking, but on natural spoken conversations. Secondly, by providing a structure for the ongoing work, the documentation could become a resource for the fire crew as part of their work practice where improved ability to make sense contributes to the result of such work. Third, in time-critical work the work rhythm and key temporal structures will be reflected in the communication and seamlessly collected and structured. The time-critical aspect of emergency response work would not provide a problem for documenting the actions but instead become a triggering mechanism. The higher intensity in the work, the more communication will occur, which in turn will result in more traces of actions to capture and make visual in the structure.

The arguments put forward of making verbal communication persistent, visible and accessible for the actors in time-critical work, are partly confirmed by prior studies. There are two studies that from different perspectives confirm the design implications. First, a study by Rogers and Brignull, on technicians in distributed teamwork [18], shows that external representations of verbal communication reduce cognitive load and improve problem solving in dynamic situations. Second, the Whittaker and Amento study of network technicians have shown how persistent and visualized speech from a voicemail system improved the coordination of solving network failures [22].

Both these studies confirm the arguments but from other perspectives of time-critical work. In the first study, the objective was to reduce cognitive load in problem-solving situations. Whereas in the study presented in this paper the focus is not on the individual tasks and prioritization between tasks but on providing accountability and thereby improving sensemaking. In the second study the point of departure was the existing voice-messages, and an invalid work process and lacking system functionality to make use of these verbal messages for problem solving and coordination. This is in contrast to the situation reported in this paper where the actors have non-existing computerized support and the verbal communication is continuously evolving as part of the ongoing work.

Mobile phone and short-wave radio communication has been widely adopted in most work settings of society for a long time now. The use of such technologies have innovated the means by which we accomplish our professional and everyday activities. However, as this study shows the increase of verbal mediated communication presents also problems for organizations where time-criticality is a core issue.

8 Conclusions

This paper presents descriptive accounts from an ethnographical field study of time-critical work in the setting of emergency response accomplished by fire crews.

Work rhythms and temporal structures of emergency response have been outlined showing that verbal communication is the primary mean for coordination in such work. Descriptive accounts have been presented that illustrates large scale rhythms and temporal structures of emergency response work, that both form and are formed by the work of the fire crew. The fire crew's actions are embedded in these temporal structures and represented in the verbal communication. The study shows that documentation has a limited role for the fire crew in the ongoing emergency response work.

Implications for design have been presented to provide answers to the research question; *how can accountability be provided in a work practice where verbal communication is the primary mean for coordination?* Accountability can be supported by designing system functionality that makes the verbal communication persistent, visible and accessible.

Making verbal communication persistent to support accountability also offers improvements for coordination and sensemaking of the ongoing emergency. Access to the verbal communication would provide currently unavailable material for post-emergency analysis.

Much work is still needed to be done in exploring the relationship between the temporal structures and the actions of the fire crew and how this could provide new and innovative approaches to improve the quality of emergency response work. This will also establish a deeper understanding of how the work will be affected by new documentation requirements that in turn are dependent on new capabilities of information technology and the actor's use of such technology.

Implementation of systems that can make visible the actions in emergency response work is both a technically and socially challenging task. There is always a risk of ending up with systems that fail to comply with

natural social behavior [8]. Seamless processing of verbal communication will form the way people accomplish their work. People will potentially adjust their actions and form new ways of interacting in relation to what traces will be collected, stored and used.

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References

1. Ancona, D. G., Goodman, P. S., Lawrence, B. S. and Tushman, M. L. Time: A new research lens, *Academy of Management Review,* 26, 4 (2001) 645-663.
2. Avison, D., Baskerville, R., & Myers, M. Controlling Action Research Projects. *Information Technology & People,* 14,1 (2001) 28-45.
3. Berndtsson, J. and Normark, M. The coordinative functions of flight strips: air traffic control work revisited. In Proc. *SIGGROUP 1999.* ACM Press (1999).
4. Camp, P. J., Hudson, J. M., Keldorph, R. B., Lewis, S., & Mynatt, E. D. Supporting communication and collaboration practices in safety-critical situations. *Ext. Abstracts CHI 2000,* ACM Press (2000), 249-250.
5. Dunn, J. C., Lewandowsky, S., & Kirsner, K. Dynamics of communication in emergency management. *Applied Cognitive Psychology,* 16,6 (2002) 719-737.
6. Fallman, D. Enabling physical collaboration in industrial settings by designing for embodied interaction. *In Proc Latin American conference on Human-computer interaction* (2003).
7. Flor, N. Side-by-Side collaboration: a case study, *International Journal of Human-Computer Studies,* 49 (1998) 201-222
8. Grudin, J. (2002) Group dynamics and ubiquitous computing, *Communications of the ACM,* 45,11 (2002), 74 - 78.
9. Hammersley, M. and Atkinson, P. *Ethnography*, Routledge, London, 1995.
10. Heath, C. and Luff, P. Collaboration and Control: Crisis Management and Multimedia Technology in London Underground Line Control Rooms, *Computer Supported Cooperative Work,* 11,1-2 (1992), 69-95
11. Klein, G., Calderwood, R., & Clinton-Cirocco, A. *Rapid decision making on the fire ground: 108.* Alexandria: Klein and Associates Inc, U.S Army Research Institute for the behavioral and social sciences, 1988.
12. Kristoffersen, S., & Ljungberg, F. "Making place" to make IT work: empirical explorations of HCI for mobile CSCW. *In Proc. SIGGROUP 1999,* ACM Press (1999)
13. Landgren, J. Fire crew enroute sense-making in emergency response. In proc ISCRAM03, (2003)
14. Nulden, U. Investigating police patrol practice. *Ext Abstracts CHI 2003,* ACM Press (2003). 820-821.
15. Orlikowski, W. J. and Yates, J. (2002) It's about time: Temporal structuring in Organizations, *Organizational Science,* 13,6 (2002), 684 -700.
16. Pettersson, M. Randal, D. and Helgesson, B. (2004) Ambiguities, Awareness and Economy: A Study of Emergency Service Work, *Computer Supported Cooperative Work,* 13,2 (2004), 125-154
17. Reddy, M. and Dourish, P. A finger on the pulse: temporal rhythms and information seeking in medical work. *In Proc CSCW2002,* ACM Press (2002) 344-353.
18. Rogers, Y., & Brignull, H. Computational Offloading: Supporting Distributed Team Working Through Visually Augmenting Verbal Communication. *In Proc 25th Annual Meeting of Cognitive Science Society,* (2003)
19. Watts, J. C., Woods, D. D., Corban, J. M., Patterson, E. S., Kerr, R. L., & Hicks, L. C. Voice loops as cooperative aids in space shuttle mission control. *In proc CSCW96,* ACM Press (1996)
20. Weick, K. E. The collapse of sensemaking in organizations: The Mann Gulch disaster. *Administrative Science Quarterly,* 38,4 (1993).
21. Weick, K. E. *Sensemaking in organizations*. Thousand Oaks: SAGE Publications Inc, 1995.

22. Whittaker, S., & Amento, B. (2003) Seeing what you are hearing:
Co-ordinating responses to trouble reports in network troubleshooting.
In Proc. ESCW03, (2003).

Paper 4

A study of emergency response work: Patterns of mobile phone interaction

Jonas Landgren & Urban Nuldén

Abstract

This paper presents descriptive accounts of time-critical organizing in the domain of emergency response. Patterns of mobile phone interaction in such work is analyzed showing how the dyadic exchange of mobile phone numbers between the actors plays an important role in the social interactions in the organizing and sensemaking of the emergency. Enacted sensemaking is used as an analytical framework. Implications for design of emergency response information technology are outlined and discussed.

Keywords

Ethnography, Enacted sensemaking, Mobile phones, Collaboration, Emergency Response

1 Introduction

The society of today is increasingly vulnerable to disturbances or collapse of critical infrastructure caused by man-made accidents or natural disasters. Efficient responses to such events are not only important to limit the consequences in a human dimension but also from environmental and economic dimensions. Emergency response and management in relation to information and communication technology (ICT) use have in the last few years gained increased attention by researchers and visibility in the Information Systems research community.

Studies of technological risks [22], organizational reliability [23] and breakdowns in sensemaking [28] indicate that accidents will continue to be an unavoidable part of everyday life. In a complex society, crisis and emergency response is no longer just a local concern involving one dedicated organization but requires the collaboration of several organizations.

Information technology is therefore fundamental in the emergency management system to mediate intra and inter- organizational collaboration.

Since a few years, Swedish rescue services under the authority of local counties or county alliances are in the process of introducing ICT in the operative incident response organization. Vehicle navigational support, mobile access to property information and hazardous material databases are applications that have gained significant interest. Rescue services in metro areas have invested in mobile command units, mobile command and control systems and wireless connectivity to the command centre network. However, integration between stationary systems and mobile systems is lacking. On a national level, a new radio-communication network is being rolled-out involving new possibilities for improved voice communication between the rescue services, the police, customs and coast guards.

There is a tendency to be an accumulation of more and more information technology especially at the operational level in emergency response work [31]. There are many ideas of what type of information technology emergency responders should use and how such technology could make a difference, less is know about what emergency actors actually use and the role of such technology.

This paper studies time-critical emergency response work and investi-

gates mobile phone interaction in such organizing based on empirical data from two major incidents.

2 Related work

Prior studies on information technology in emergency response settings include; studies of incident command structures [2], information technology as an organizing resource [3], key functionality in emergency management information systems [26], improved design of radio communication on the fire ground [4], ubiquitous computing to improve accountability and awareness for the fire crew [10].

Within the field of HCI and CSCW, a number of studies have focused on work in time and safety-critical work, including air-traffic control [9], subway crisis management [8] and emergency response centers [21, 18]. Other studies have focused on extreme or radical collaboration [16, 25] in war-room settings as a response to an organization's complex engineering problems. Studies of medical emergency response work practice have focused on design ideas based on the victim [11] as boundary object. Studies of the work practice of fire crews have explored preparation activities enroute to accident locations [12] and how temporal rhythms in small-scale incidents could be one input for improved accountability [13] and sensemaking.

It has been claimed that CSCW-system designs assume that the workers are organized into teams with clearly defined and stable roles [17]. These systems are designed to support users within one organization with a predictable structure of workplace interaction. At the same time it is clear that relationships outside the organization are critical to most organizations. These relationships, with clients, suppliers, government, and others, are often ICT mediated and computer based systems for collaboration and cooperation, and virtually extended outside the organization.

Many organizations put tight boundaries around their networks to restrain communication from leaving, and communication from entering the organization. Whereas there are many types of ICT used in organizations, there is one technology that is more reluctant to adhere to organizational borders than others; the mobile phone.

Studies of mobile phone use in professional work have shown how this technology has had impact on the temporal boundaries of the work day [20]. Further, studies of police work have shown that mobile phones allow changes in intra-organizational role relations with co-workers as well as in inter-organizational relations with the public [15]. One of the key aspects of the mobile phone is that the mobile phone number provides the only fixed address to otherwise flexible, independent and mobile individuals [1]. Studies of the relief work after the Katrina Hurricane shows that mobile phones was used for communication between ephemeral response groups and the first communication technology that became operational in the aftermath [5].

Based on empirical data from two major chemical hazard incidents, this paper will investigate mobile phone interaction in the organizing of emergency response work. Enacted sensemaking is applied as an analytical framework.

3 Enacted sensemaking

When professional actors such as firefighters, respond to an emergency they become part of the emergency through their actions to make sense of the situation and their actions to prevent an escalation of the emergency. From a sensemaking [29] perspective, formulated by Karl Weick, it is understood that people think by acting and that action preludes understanding. This means that when professional actors make an intervention to an emergency they also *"simultaneously generate the raw material that is used for sensemaking and this affects the unfolding of the crisis itself"* [27]. People construct meanings of an event when they compare what they see with what others see and interacts to form some mutually acceptable version of what exists. Based on this line of argumentation, the term enactment is powerful in explaining *"when people act, they bring events and structures in to existence and set them in motion"*. Enactment is a social process [27] of *"material and symbolic record of action"* [24]. The result of this process is an enacted environment consisting of real objects such as toxic material, risks, people, cargo wagons and valves. These objects are real but their meaning and significance are subject to multiple interpretations [27].

The capacity in terms of the number of actors and the competence of those actors available to do the acting and interpretation are crucial vari-

ables. This is a collective process [29] which means that successful interaction between people in equivocal situations enable them to see more ways to intervene and decrease the escalation of the crisis [27].

The emergency response work and the accident environment are enacted through the social interaction between the key emergency organizational actors [24]. This means that organization emerges through sensemaking, not that sensemaking is a product of organization [30]. In order to study emergency responses and the effort of organizing such work, the focus must be put on the social interactions of the involved actors and specifically on the information technology used by people in such work.

4 Research setting and method

This section describes the rescue service, and briefly the police and the SOS-112 and their relationships in emergency response work. Next, the method is described. Following to this are the two incidents presented using descriptive accounts of the response work of the first day of the two major incidents involving hazardous material.

4.1 Key emergency organizations

In the event of accidents involving an immediate and substantial threat of harm to humans, property or the environment, emergency response operations are organized by the rescue services, sometimes referred to as the fire brigade.

The incidents presented in this paper took place in a region having a rescue service organization consisting of a 24/7 operational command centre, mobile command units and a range of specialized rescue units with fire crews of 4-6 firefighters in each unit. The organization has eleven full-time fire stations and additional part-time stations. The operative work conducted by the rescue services during incident response is the responsibility of an incident commander. The incident commander is a role that only exists during incident response. In small-scale incidents and in the initial work in large-scale incidents, a fire crew commander is assigned as the incident commander, but as an incident develops, the role of incident command is transferred to higher-ranking commanders.

In addition to the rescue service, other organizations are also key actors in emergency response work such as the SOS-112 emergency call center organization and the police. When calls are made to the 112-emergency number, an SOS-operator receives the emergency calls, makes initial situation assessment and if necessary transfers the calls to the fire & rescue and police command centers, and coordinates resources of the emergency medical service. The police are organized in similar structures as the rescue services including a 24/7 command centre, mobile command units, and a number of operative patrols.

4.2 Method

Since 2002 the two authors have conducted extensive research on police patrol and fire crew work [12, 13]. Based on an ethnographic [7] approach, the two authors have made over 1900 hours of fieldwork. Participant observations have taken place as part of fire crews' and police patrols' work shifts. The rich and large amount of material from this fieldwork is used for providing a deep understanding of information technology use in such work practice.

This paper reports from two large-scale accidents happening at the same geographical location. Data has been collected through observation, interviews and document analysis. In the 2005 accident, one of the authors arrived to the accident location three hours into the incident. The observations of this incident covers seven hours of work at the accident location from around 17:00 until midnight. In the accident in 2006 the same author was doing a field work at the same rescue service organization. Observations from this incident cover 7 hours of work. The observations and recordings of verbal communication could therefore start immediately. In both accidents the observations were focused on the work of the incident commander.

The observations were documented as field notes in a paper notebook and later transcribed. By using a digital recorder, verbal communication consisting of radio-talk, mobile phone communication as well as face-to-face discussions was recorded. Episodes of this voice communication material were later transcribed. A selection of documents, artifacts and people were photographed in order to provide rich material for the following detailed analysis. The analysis started with a thematic analysis of the transcribed field notes. This analysis gave indications that mobile phones and contact information had an important impact on the organizing of the

response efforts. This observation triggered a second set of data collection activities including retrospective interviews.

Semi-structured interviews [19] were conducted with key actors in the rescue services organization; the crew commander of the first arriving response units, the two incident commanders working during the first twenty-four hours of the incidents, the commander of the incident support organization. Each of these persons was asked to reflect in retrospect on the work during the first day of the incident and recollect how contacts were established and maintained as part of this work. Phone records of the commander's mobile phone use were not possible to obtain.

The interviews were made with one individual at the time and took place in meeting rooms at the rescue services. Each interview lasted between 60 and 80 minutes and was recorded and transcribed. The interviews were followed by an analysis of documentation [19] produced during the incident. The documentation consists of the rescue services command logs from the command post at the accident location and the command centre. In addition to these documents, command logs from the police authorities and evaluation reports have also been analyzed. The command logs were compiled into one event-log to provide a richer view of the critical events and the involved actors actions.

The analysis started by aligning the transcribed field notes to the timeline of the complied command log. When a mobile phone number and an actor were found in the log, the corresponding field note was used to explore the circumstances at the accident site around the same time. This was repeated for each entry in the command log for the time periods covered by the observations. The same procedure was then repeated but starting from the field notes and relating to entries in the command log. This was followed by an analysis of events and actions of the response work when additional actors or new information emerged. These events were then explored in relation to the retrospective interviews with the different commanders. The analysis of the field notes and the command log resulted in patterns showing that people and mobile phone numbers were a crucial and primary set of information in order to organize the response work.

4.3 Descriptive accounts of the two incidents

4.3.1 The 2005 incident

On the 28th of February 2005 at 12:50 a cargo- train with 720 tons of chlorine derailed on a field near Ledsgard, 1.5 km south of the village Anneberg on the Swedish west coast. This event triggered a massive response operation that lasted for seventeen days and involved over twenty different organizations.

Eyewitnesses to the accident called via mobile phone to the national emergency dispatch organization, SOS-112, and reported that a train had derailed. This call was re-routed to the rescue services. The rescue service command centre dispatched a first responding unit from the fire station nearby the accident location. This fire crew arrived within a few minutes to the location. The accident location was on a field with no direct roads leading towards the derailed train. There were no smoke clouds from a chlorine leakage visible around the train and four of the firefighters in the crew including the fire crew commander started to walk across the fields towards the train, a distance of approximately 500 meters. A few minutes later, a service technician from the railway company arrived to make sure that the electricity was cut off. The fire crew commander exchanged mobile phone numbers with him. In accidents as this one, involving hazardous material, a fire engineer and an assistant operator are automatically dispatched to the incident along with a range of fire units.

> "When I received the alarm here at the fire station, the information was limited, I was informed that it was a train, a cargo train with hazardous material. So we start to drive to the location. Half way to the location we were contacted and I got the information that it is a train with twelve wagons, several of the wagons have derailed, and the wagons contain chlorine. I realize that this is a really big a complex accident...It was emotionally stressful." (The Fire Engineer)

When the fire engineer arrived to the accident location, a command point was established a few hundred meters north of the train. The fire engineer was unable to get in contact with the fire crew commander over radio and instead took contact via mobile phone. Detection instruments were handed to the local fire crew to monitor for potential leakages. The instru-

ments gave negative results. Shortly after the first police patrol arrived, followed a few minutes later by the arrival of people from the cargo company and the health authorities. At the time when media arrived, the accident location had become a bit crowded with people from several organizations. A command vehicle and a mobile command room formed the physical structures at the command post.

At the 19:15 conference at the command post on the accident location, involved a large number of actors. The conference took place in the mobile command room that basically is a rebuilt cargo container. Due to the physical limitations of this space, only one actor from each organization was invited to this meeting. The following excerpt from the incident commander, illustrates the situation:

> "Do we have all the organizations here, do we miss anyone? ...the wagons have derailed here, they are severely compressed and that is especially the case for the engine and the first four wagons, also the fifth wagon is affected...These wagons are squeezed together and partially derailed. We have had experts onsite to have a look and they cannot determine how safe it is."

> "We have very limited information about the risks. My assessment and decision for the night is that we are not going to start any major activities here during the night because of the risks with work in darkness and associated risks for the personnel." During the night we will continue to collect information and prepare potential activities starting in the morning. That is the big picture."

> "One problem we face right now is the access to the wagons, I have asked the police to have a look at the access restrictions."

The conference resulted in a situational 'freeze' of all actives to remove the train and wagons from the location. At this point it became clear that it would take several days until the cargo wagons will be removed. During the evening, the incident commander coordinated with the police how to organize an evacuation if that would become necessary. After the conference, actors from the cargo company and the chemical producer together with the incident commander discussed the necessity to bring in additional expertise to the location to provide a more qualified damage assessment of the wagons.

It took seventeen days and the involvement of over twenty different organizations to remove the derailed train and open the railroad for traffic. It was evident that the temporal dimension of the accident was far from well understood in the initial response work. The extension in time was gradually evolving as a result of the collective efforts to make sense of the situation and the possibilities for intervention.

4.3.2 The 2006 incident

On the 4th of August 2006 at 20:19 an almost identical alarm as the 2005 incident was sounded at the main fire station in Gothenburg. "Railroad accident, chemical material, Ledsgard, Anneberg". At this moment the night-shift fire engineer was interviewed by one of the authors regarding lessons learnt by the organization of the chemical accident in 2005. The fire engineer and the researcher looked at each other and for a moment they could not believe what they just heard, the same location, the same type of accident as last time. After a second or two the two very surprised individuals left the coffee room and went rapidly down to the command vehicle, where the command assistant met up.

Concurrently, the fire crew in the southern district was dispatched along with an operative onsite commander from another district. During the transportation phase to the accident location contact was established over mobile phone between the fire crew commander and the operative onsite commander in order to determine a safe approach route. During the next twenty minutes additional fire crews were dispatched and enroute to the accident location. The fire engineer in the command vehicle had several contacts with the command centre while enroute to the accident location. The chemical cargo of the train was proven to be ethylene oxide and communicated to all fire units.

The primary objective in the initial work on the accident location was to build up a massive water system that could be used to cool the chemical tanks as well as reduce the consequences of a potential fire. The first few hours were focused on the activities to build up a water suppression system, being both time-consuming and resource intensive. During this work arrived additional actors, such as the Cargo company, railroad-representatives, paramedics, media and county representatives to the accident location.

One of the important activities was to make a damage assessment of the derailed cargo wagon. A fire crew was equipped with sensor instruments and a digital camera in order to check for leakages as well as take pictures of any damages. The result from the sensor instruments gave negative results, meaning no measurable leakage. But the visual inspection of the wagon indicated that there was a small leakage from a valve on the bottom side of the tank just a few drops a minute but still a leakage. This discovery resulted in ambiguity. The instruments gave no indication but the visual inspection did. The actors made sense of the situation by relying more on the visual indication than on the sensor instruments of which they had only little experience of using. This lead to the interpretation that there is a small leakage. When the chemical experts arrived two hours into the incident the situation was far from clear and the message from the expert was received with mixed feelings in the following situation brief that took place. The incident commander informed that:

> "Ethylene oxide is among the worst substances...I would argue that it is even worse than chlorine...it is very toxic and highly flammable" "We have a very small leakage...and we will not make any actions at this point that can endanger the integrity of the tank...we are awaiting the arrival of a wagon expert." "We also have many citizens in this area. The police has blocked the roads and they are also helping out in cases of an evacuation"

One of the fire crew commanders (FCC) had questions to the chemical expert, asking:

> **FCC:** If it catches fire...how fast will it develop?
>
> **Chemical expert:** There are not many people that have been able to share experiences of that...a fire must be avoided.
>
> **FCC:** How large is the risk zone?
>
> **Chemical expert:** The safety distance is 1500 meters.
>
> **FCC:** Due to a fire?
>
> **Chemical expert:** The explosion.

The response by the expert shows how serious the situation was understood to be. In a phone conversation, after the situation brief, the incident commander (IC) informs the regional police about the situation and the expected time frame for the response work.

> **IC:** In my opinion this will take several days.

During the late night an additional chemical expert arrives and the two experts conduct an inspection of the cargo wagon using very sensitive sensor instruments. After this inspection, the situation changes dramatically in a positive direction. Their instruments did not give any indications of a leakage and their explanation to the leakage is that it is water condensation from the cold toxic substance. In the following morning plans for the removal of the dislocated wagon were outlined and by late afternoon were the railroad restored to normal traffic.

This second incident shows the enacted sensemaking of the involved actors and how their collective efforts provided material to initially interpret the situation as highly dangerous. When more information became available, the capacity of the actors increased and the visibility of the situation improved. By the use of additional instruments and competences, eventually resulted in an interpretation that allowed the actors to complete the response work.

In the next section we will present findings from the analysis of these two accidents.

5 Findings

The organizing of incident response to a large-scale and critical accident triggers activities to establish a network of affiliated persons. The structure emerging from these activities is a network of names of people with mobile phone numbers along with organizational affiliation rather than a structure of organizations and roles with anonymous or black-boxed individuals. The individual affiliated actors become nodes of expertise in the response network. The phone numbers documented in the logbook make references to individual actor's mobile phones and only in a few

occasions to organizations' switchboards. The focus on actors is related to the importance of having continuity in the communication, which is especially important during the initial work in response work.

Mobile phone interactions were observed among the fire commanders and the external actors. The radio was only used to communicate with the fire crews. Overall, the conversations over radio and mobile phones were not bursty and short, as one perhaps could expect in time-critical situations. We did not observe any breakdowns in the mobile phone network or disturbances due to network overload. However, in the 2006 incident, the incident commander had significant problems with his mobile phone due to low-battery capacity.

The analysis of the incidents shows examples of three patterns of interactions in organizing a response network where the mobile phone had a fundamental role. These patterns are non excludable and to some extent overlapping. The labels signal the direction or lack of direction of the interactions. The patterns of interaction are serendipitous interaction, inbound interaction and outbound interaction.

5.1 Serendipitous interaction

The incidents presented in this study represent not only breakdowns of critical infrastructure but they are also major and severe accidents. Such events trigger multiple organizations to become involved in the direct response efforts. The initial work by the involved organizations is characterized by multiple, rapid and independent response with only limited coordination. The primary activity in the initial work is to define the location and relocate actors to the scene of the accident in order to make sense of the situation and to limit the consequences by reducing the risk for an escalating and uncontrolled situation.

When the rescue service receives an alarm regarding hazardous material from the SOS-112, they initiate a response according to a predefined plan for chemical accidents. This includes dispatch of a local first responder unit, a mobile command unit and a specialized chemical/hazmat unit. Concurrent with these activities, are the railroad company and the cargo company acting in order to send staff to the location. These three organizations, the rescue service, the railroad company and the transport operator, became rapidly involved in these two incidents but with different perspectives. The rescue services focus on the hazardous material and potential consequences for the people in the area. In these incidents, the initial actions from the various actors focused on approaching the situation from their respective responsibility. The railroad company focused on providing a safe area around the train, cutting the electricity and exploring the possibilities to run traffic on the undamaged parallel rails. The cargo company focused on the train driver and on the status of the cargo. The three organizations have their particular share of the incident and could be seen as part-owners of the incident. The initial work is carried out with limited coordination between the actors and provides occasions for serendipitous interaction.

The concurrent and independent responses from multiple organizations affect the forming and establishment of a network of collaborating actors. Due to the time-criticality of the situation and the need to reallocate individuals to the location in order to make sense of the situation, a highly coordinated response is difficult in the initial phase of response work. The dispatching of actors to the accident location provides opportunities to connect with other actors that have part responsibility in the subsequent work. The unintentional meeting between the fire crew commander and the railroad representative is here seen as serendipitous interaction that creates connections between two important actors in the emergent network of response actors. The fire crew commander explains:

> "When we were walking along the train I met the railroad guy. I didn't order him to the location. He told me to hurry up because his organization wanted the railroad to be reopened for traffic. I told him to slow down this will take time. I also got his phone number and typed-in the number and called and hung up, making it quickly available at the time."

In this case it resulted in an exchange of phone numbers. The contact management by the fire crew commander indicates that phone numbers to other actors on the accident location are important. Neither of the actors ordered the other to be on the location or knew the location of the other up until that time. The actors had their unique task in relation to the accident and the physical co-locatedness provided the serendipitous interaction leading to an initial structuring of a network of actors for the subsequent joint-work.

5.2 Inbound Interaction

The incident commander has the overall responsibility for an emergency response operation and is highly dependent on experts from other organizations to get a sense of control over the situation. In large-scale incidents with a direct threat of toxic leak, the incident commander must act on different time-scales [6] to comply with short-term issues as well as trying to think ahead of the situation.

In addition to the directly involved organizations, within the first hours a number of organizations arrived to the accident location, such as people from the railroad company, the cargo-company as well as the media and county authorities. The establishment of the command post by the fire engineer and the role switch of the incident command role from the fire crew commander to the fire engineer form new means to manage the network of actors. The incident commander explains:

> "The first on-location-contact I had was with the crew commander and it did not work well over radio so I finally called him on his mobile phone. We started to send out firefighters with indication devices to monitor for potential leaks. Pretty soon additional people from external organizations arrived and especially the railroad company was very quick, half an hour in to the work and they had five-six-seven people and it became messy, they are used to work along rails and started to move freely. An electricity- guy started to cut the power and I had to tell them quite sharply not to walk close to the train. The police did also arrive quite fast but only with a patrol with one guy."

The sheer number of people, arriving to the accident location, put pressure on the incident commander to determine what people should be at the location and who should not be there. The incident commander explains:

> "People that arrive, they approach you and there is much face-to-face communication, In this situation everyone goes to the fire trucks at the command post... that is not always good if something critical would happen, but at the same time I need people close to me because of their expertise, but it is difficult to determine who should be close and who should leave [the command post.]"

The excerpt shows that people from the various organizations arriving to the accident location present difficulties to the incident commander. A problem is to make clear who are important to have close connection to and whom should be kept at a larger physical distance. An incident commander explains:

> "You say to the command operator; make sure that these people stay here at the command post so I can reach them when I have time. An alternative is to take their mobile phone number. So it is a lot of phone talk."

What is seen here is inbound interaction characterized by the face-to-face communication with newly arrived actors. Inbound interaction includes a mechanism to determine the needed proximity for the actor and if the actor will become a legitimate actor in the response network. The exchange of mobile phone numbers between the external actor (P) and the command operator (CCO) form the mechanism to, on location, become part of the contact network. The following excerpt shows an example of such inbound interaction when an expert from the chemical company arrives to the command post:

> **P:** Malcom Larsen, ChemCo.
>
> **CCO:** Peter... command assistant, you have to wait for a few minutes for the incident commander.
>
> **P:** Okay.
>
> **CCO:** What is your phone number?

At the time of the expert's arrival to the command post, the incident commander is unavailable for conversations due to coordination issues with a senior commander. The command operator asks the person to wait and takes his phone number. Inbound interaction is not restricted to the physical arrival of people to the accident location. There is also inbound interaction when individuals make phone calls directly to the incident commander or contacts the command operator at the command post. The following excerpt illustrates this type of inbound interaction:

CCO: Hey... the regional police in H-county is calling and wants to talk to you.

IC: Take his number and tell him I will call back.

The excerpt shows that the incident commander is acknowledging the legitimacy of the interaction as such but needs to postpone the conversation with the police due to the ongoing work. The request and the subsequent exchange of phone numbers signals that the call will be made by the incident commander when an opportunity for that conversation is available to him.

The collection of phone numbers that accumulates as part of these interactions are first scribbled on paper notes and later added to a growing list of numbers and names on a paper document. A selection of these becomes available on the whiteboards on the outside of the command vehicle, but they are not explicitly handed-out to the involved actors.

5.3 Outbound Interaction

When an accident is understood as a complex incident, the rescue service activates an incident support staff organization. The structure for this organization is pre- planned but nevertheless such activation is not instrumental and immediate, but delayed due to the physical relocation of people to the command centre. Further, the work of the support staff in the initial phase is highly oriented to move ahead of the incident and get an understanding of what, where and who are currently involved in the already ongoing work. The chief of support staff explains:

> "I became involved in the work quite soon. We did not get more information than, that a train has derailed and there are a few wagons with chemicals, they didn´t have more [information] and would come back."

Based on this information from the command centre, the chief of support staff and one assistant started the work of activating the incident support organization. One of their priorities became to establish a contact network. The establishing of a contact network was managed not based on a predefined sequence but more dependent on the experience of the two people working in the incident support organization:

> "Based on my experience of being a former chief of command centre and the knowledge from the time as an operator, we contacted organizations that have chemical experts both in the region as well as from the national units. So it was more or less just for us to start up a contact network and inform that we have an accident. What resources do you have if we need your help."

In this work, a number of contacts were made with organizations that had chemical expertise and resources that could be sent to the accident location. Access to expertise in critical and complex incidents is necessary and fundamental for the response work. The chief of the incident support organization explains:

> "A chemical accident is a tough situation where a number of actors must be involved, the rescue services would fail if we had no access to experts and the experts need to be on location and there will be a set of phone numbers."

As a result of the outbound interaction, a list of names and phone numbers is formed and documented continuously along with a time-stamp in the command log only in use at the command centre. The list of names and numbers forming the contact information includes notes regarding on when to make contact. On a few entries in the command log, include notes specifying the activities certain people were currently engaged in at the moment of contact, such as that certain persons are on their way to the accident location or that someone will attend the staff briefing. Outbound interaction is also evident in the work on the accident location. The need to bring in additional actors in the work results in a search for phone numbers that provide direct contact to such actors.

5.4 Dyadic exchange of phone numbers

The analysis of the three patterns of interactions has also identified how mobile phone numbers are exchanged on a more concrete level. The dominant form of mobile phone number exchange is that one actor, such as the command operator, acquire a phone number by asking the mundane

question *"what´s your number?"* to an external actor. We view this as the number is taken by the emergency professionals, based on an understanding that this particular actors phone number is of interest for the incident command. The number is then included in the paper list forming a contact structure and made available on a whiteboard at the accident site. The acquisition of phone numbers is not just a practical solution to form a contact list but also a social mechanism to signal that a certain individual is an important actor in the response work.

A variant of the acquisition of phone numbers is provision of phone numbers. This form is used when the phone number is not intended for the individual that acquires the number but for some ´third´ individual not part of the current dyadic exchange. The excerpt show how the policeman asks for the IC phone number and declare that the number is for someone else and will be passed on to a high-ranking commander in the police organization.

> **Police on-site:** The phone number to you [incident commander] so I can give it to the regional police commander.

The provision of phone numbers has consequences on the communication structure and can lead to break-downs. The break-down is here conceptualized as by-passed institutionalized order. The communication and interaction between people engaged in emergency response work follows to some degree the philosophy of the hierarchical structure also known as the incident command system [2].

However, the qualities of mobile phone technology allowing a direct point-to-point communication is also providing opportunities to explicitly and publicly by-pass the institutionalized hierarchical system. The following excerpt shows how the mobile phone number to the incident commander (IC) has become shared and later provides disturbances in the communication structure.

> **IC:** Yeah...hi...IC Anneberg here..
>
> **IC:** You have to talk with your paramedics commander, the ones you have here...I have made a situation brief for them. Yes...but... you will...but you will get it via your paramedics commander here...it is unreasonable for me to have contact with the police and paramedics on-site as well as their managers.

The phone number in this excerpt was delivered to the regional ambulance commander that called the incident commander, despite the fact that the paramedics were on-site.

6 Conceptual design

In the previous section the descriptive findings of the analysis of the emergency response work is outlined. These findings show pattern of interactions between the various actors in order to organize the emergency response. Serendipitous, inbound and outbound interaction patterns are part of the enactment process [27] of the collective sensemaking efforts. The exchanges of mobile phone numbers are embedded in these interaction patterns and influence the ability of making a professional intervention.

Looking at mobile phone interactions in this context offers new insights into design of information technology use for time-critical organizing. The current use of mobile phones in emergency response work is to mediate verbal communication. But as the findings show the use of mobile phones also provide the ability to socially form and manage a network of actors across organizational boundaries in response work and thereby improving the capacity of enacted sensemaking [27].

These findings indicate that the mobile phone could become the infrastructure for both verbal communication as well as information sharing in emergency response work. As seen in the findings, emergency response span across organization boundaries. This means that in the event of an incident, the professional organizations would benefit of a common information channel covering the involved actors for mediation and sharing of non-verbal incident specific information. This means that symbolic record of actions, such as status reports, maps and photos produced during the intervention would become available for all the involved actors and organizations.

Implications for such system design is to avoid adding yet another system and additional artifacts for the emergency response actors but to make use of the technology that is already in use and base the design

on the existing social organizing patterns. The key implications are: 1) the design entity should be the fixed address to the actor, in this case the mobile phone number, 2) the design should address the situated management of phone numbers providing both social and technical functionality. These two key issues have the potential of focusing the design of an incident specific information channel that is publicly available for all the actors that become part of the response network.

The following high-level description illustrates what such design could materialize in. When new actors are included in the response network through the exchange of mobile phone numbers they should also at that moment have access to the incident specific information channel. The incident specific information channel should be available to all actors in the rescue services via their network enabled personal communication devices such as their mobile phones. Such information channel should only be available in cases of an incident and during the response work. As long as the response is ongoing, the incident specific information channel will also be available. When the acquired phone number is added to the incident specific information channel it could result in a message that is pushed to the corresponding mobile phone and thereby provide authorization and access. The addition of a phone number should be supported at all localities where mobile phone numbers are managed; at the command centre, at the command post, and also via mobile phones of field personnel.

The incident specific information channel is envisioned to make use of technologies such as full-capacity mobile web-browsers, real simple syndication (RSS) and blogging functionality now becoming standard features in consumer mobile phone products. Information systems previously restricted by organizational boundaries will be able to publish or push information to the incident specific information channel. The information made available in the incident specific information channel could be accessed on mobile phones and when necessary, due to limitations of the handset or for actors in non-field settings, be transferred to laptops or other devices.

The suggested design contrasts solutions designed from a large-scale medical emergency management perspective [11]. The design proposed here in this paper is based on the idea that small-scale accidents can quickly escalate to large-scale crises and that the response work in the initial phases of an emergency have small-scale qualities. The focus on mundane technology such as the mobile phone and using a bottom-up perspective is targeting the issue that emergency response information technology must be both technically scalable as well as socially scalable. Further, in the study of the Katrina Hurricane relief work [5], it was shown how dyadic interaction formed the basis for information sharing and collaboration across organizational boundaries. The study also presents that introducing new technology for ephemeral response groups proved to be difficult. In contrast, our design focuses on making better use of the technology already in place among the response actors.

The formation of the response network to provide both technical as well as social connectedness is managed on the social level compared to more technical level where the connectivity is provided on the device [14] seamlessly and automatically using for example Bluetooth. Our design does not remove the social aspect of connecting actors but rather use the social contract that the exchange of mobile phone number could be interpreted as. The design implications presented here focus on the use of mobile phones not only to maintain a social network in a symbolic meaning but also to provide a materialized information infrastructure where mobile phones mediate both network connectivity, social connectedness and information sharing which is understood as key characteristics in enacted sensemaking [27, 29]. However, the consequences of such design are difficult to project. The flow of information in the incident specific information channel will most probable put new demands on the actors. For example, expectations to be continually updated and being accountable for actions beyond their authority due to the visibility of collective actions. Further, technology pre-structures how people are able to understand their world [29] and so does also the design outlined here and the materialization of such design. Alterations of such social patterns must be done with care.

7 Discussion

In Sweden, the regional fire and rescue service organization has the comprehensive responsibility for incident response and management. A vast number of computer systems have been designed, implemented and put to use within these organizations. These systems are used by the organizational members and serve as the backbone support for the organizational

processes. However, when a more complex incident has occurred additional actors and competences have to be acquired rapidly from outside the organization. These actors are most often excluded from the organizational information systems and cooperation with these external actors has to be through other means than through these systems.

In this paper it has been shown how actors use mobile phones to interact, negotiate and establish the initial network of professionals in order to meeting the threats posed by a major incident. Emergency response organizing was analyzed from an enacted sensemaking perspective. Patterns of mobile phone interaction were presented showing how they are embedded in work of organizing socially connected actors part of the response work resulting in an increased capacity for sensemaking[27]. Three interaction patterns were outlined: serendipitous, inbound and outbound. These patterns have also been observed on other incidents but on a smaller scale.

In serendipitous interaction mobile phone numbers are exchanged face-to-face and only individually available. This was illustrated in the case where two actors independently of each other were dispatched to the incident by their respective organizations. In inbound interaction, various actors offer their expertise to the response network and if their expertise is considered as relevant in relation to the incident at hand they are accepted as a legitimate actor in the response network. The challenge here is to balance the inbound interaction to central actors as for instance the incident commander. Outbound interactions are of two kinds. First, when an actor simply is informed. Second, when a resource is called in to be a legitimate actor in relation to the incident. This can be either an actor with a specific expertise such as the chemical expert who came to the two incidents. It could also be an outbound reach to the regional police commander that analyzes evacuation plans for the incident from a distance.

The significance of this paper is discussed from two perspectives. From a practitioner perspective, i.e., fire and rescue service, is it shown that the mobile phone is of crucial importance for the process of organizing the work to meet the initial demands posed by the incident. The communication within the rescue service can be managed through the radio communication system. However, communication with other organizations has to be mediated through alternative channels such as mobile phones. From a research perspective the contribution of this paper is the detailed descriptions of the patterns of interactions of mobile phones in time-critical organizing. The ethnography may inspire design activities targeting time-critical organizing. The conceptual design illustrates contrasting views to previous studies that are related to the application domain of emergency response systems as well as technical solutions for ad-hoc connectivity. The results from this paper address on a general level, the design of information technology for ephemeral work groups. Such groups are not only found in emergency response or disaster relief work. Settings with similar characteristics include physical restoration of telecom/power infrastructures, and in general the work of field service technicians. However, additional studies are needed to further generalize these findings.

8 Conclusions

This paper has discussed time-critical organizing and investigated mobile phone interactions in this organizing. The analysis shows how the mobile phone not only have an important function as a communication device but also how the mobile phone numbers are used in organizing and making sense of the emergency. The analysis outlined three patterns of interactions where dyadic exchanges of mobile phone numbers could be seen as embedded in the enactment process of the collective sensemaking activities. High-level design implications have been discussed to illustrate the implications for future systems aiming to improve emergency response organizing.

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References

1. Arnold, M. On the phenomenology of technology: the "Janus-faces" of mobile phones." Information and Organization 13,4, (2003) 231-256.
2. Bigley, G. A. and K. H. Roberts . The Incident Command System: High-Reliability Organizing For Complex and Volatile Task Environments. Academy of Management Journal 44,6 (2001) 1281-1300.
3. Calloway, L. J. and P. G. W. Keen. Organizing for crisis response. Journal of Information Technology 11,1 (1996) 13-27.
4. Camp, P. J., Hudson, J. M., Keldorph, R.. Lewis, S., Mynatt, E.D. Supporting communication and collaboration practices in safety-critical situations. In *Proc. CHI 2000,* ACM Press (2000).
5. Farnham, S., Pedersen, E., Kirkpatrick, R. Observation of Katrina/Rita Groove Deployment: Addressing Social and Communication Challenges of Ephemeral Groups In *Proc. ISCRAM 2006*, (2006).
6. Fredholm, L. Decision-making patterns in major firefighting and rescue operations. In Decision Making under stress: Emerging themes and applications. Ed: R. Flin, E. Salas, M. Strub and L. Martin. Vermont, USA, Ashgate Publishing Company, 1997.
7. Hammersley, M. and Atkinson, P. Ethnography, Routeledge, London, 1995
8. Heath, C. and P. Luff. Collaboration and Control: Crisis Management and Multimedia Technology in London Underground Line Control Rooms. Computer Supported Cooperative Work 1,1 (1992) 24-48.
9. Hughes, J. A., D. Randall, D. Shapiro. Faltering from ethnography to design. In *Proc. CSCW 1992*, ACM Press (1992).
10. Jiang, X., Chen, N.Y., Hong, J.I., Wang, K., Takayama, L., Landay, J.A. Siren: Context-aware Computing for Firefighting. In *Proc. Pervasive 2004*, (2004).
11. Kristensen, M., Kyng, M and Palen, L. Participatory design in emergency medical service: designing for future practice. In *Proc. CHI 2006*, ACM Press (2006).
12. Landgren, J. Supporting fire crew sensemaking enroute to an incident. International Journal of Emergency Management 2,3 (2005) 176-188
13. Landgren, J. Making action visible in time-critical work. In *Proc. CHI 2006*, ACM Press (2006).
14. Lorincz, K. Malan, D.J. Fulford-Jones, T.R.F. Nawoj, A. Clavel, A. Shnayder, V. Mainland, G. Welsh, M. Moulton, S. Sensor networks for emergency response: challenges and opportunities. Pervasive Computing 3,4 (2004) 16-23.
15. Manning, P. K. Information Technology in the Police Context: The "Sailor" Phone. Information Systems Research 7,1 (1996) 52-62.
16. Mark, G. Extreme Collaboration. Communications of the ACM. 45,6 (2002), 89-93
17. Nardi, B., Whittaker, S., Schwarz, H. NetWORKers and their Activity in Intentional Networks. Computer Supported Cooperative Work 11 (2002) 205-242.
18. Normark, M. Sense-making of an emergency call: possibilities and constraints of a computerized case file. In *Proc. NordiCHI 2002*. ACM Press (2002).
19. Patton, M. Q. Qualitative Evaluation and Research Methods. SAGE Publications, London, United Kingdom, 1990.
20. Prasopoulou, E., A. Pouloudi, Panteli, N. Enacting new temporal boundaries: the role of mobile phones. European Journal of Information Systems 15,3 (2006) 277-284
21. Pettersson, M., Randall, D., Helgeson, B. Ambiguities, awareness and economy: a study of emergency service work. In *Proc. CSCW 2002*, ACM Press (2002).
22. Perrow, C. Normal accidents. Basic Books New York, 1984.
23. Roberts, K. H. Some Characteristics of One Type of High Reliability Organization. Organization Science 1,2 (1990) 160-176.
24. Smircich, L. and Stubbart, C. Strategic Management in an Enacted World. The Academy of Management Review 10,4 (1985) 724-736.
25. Teasley, S., Covi, L., Krishnan, M.S., Olson, J.S. How Does Radical Collocation Help a Team Succeed? In *Proc. CSCW 2000,* ACM Press (2000).
26. Turoff, M., Chumer, M., Van de Walle, B., Yao, X. The Design of Emergency Response Management Information Systems. The Journal of Information Technology Theory and Application (JITTA), 5,4 (2004) 1-35

27. Weick, K. E. Enacted sensemaking in crisis situations. Journal of Management Studies 25,4 (1988) 305-318.

28. Weick, K. E. The Vulnerable System: An Analysis of the Tenerife Air Disaster. Journal of Management 16,3 (1990) 571-594.

29. Weick, K. E. Sensemaking in organisations. Thousand Oaks, SAGE Publications Inc. 1995

30. Weick, K., Sutcliffe, K,. Obstfeld, D. Organizing and the Process of Sensemaking. Organization Science 16,4 (2005) 409-412.

31. Quarantelli, E. L. Problematical aspects of the information/communication revolution for disaster planning and research: ten non-technical issues and questions. Disaster Prevention and Management 6,2 (1997) 94-106

Paper 5

Investigating the tension between information technology use and emergency response work

Jonas Landgren

Abstract

A major challenge of mobile information technology use in time-critical work settings is to balance the temporal impact on the work practice caused by the technology. This paper presents results from an investigation of the tension between information technology use and temporal aspects in the time-critical work of emergency response. This paper contributes to previous research on the inter-related relationship between the temporal aspects of the work practice and the use of information technology. Results from a study based on participatory analysis indicate how technology can be designed and introduced to comply with temporal aspects in a work practice characterised by rigid temporal structures.

Keywords

Temporality, Field experiment, Participatory analysis, Emergency response work

1 Introduction

Emergency response and crisis management has in the last few years become an arena for major investments in sophisticated information technology. Recent man-made disasters such as the World-trade center disaster and natural disasters such as the one partly caused by the Katrina hurricane, have shown that the modern society is still far from being able to make suitable responses to crisis and emergencies. As a consequence of a few extreme events, significant efforts are now being made to design various emergency management information systems that can support and improve the work on organizational levels and inter-organizational levels in case of emergencies or crisis.

Such initiatives exist on almost all levels in society, in local counties, regions as well on national levels. Independently of the scale of the emergencies or crisis, these systems are designed to provide improved situation awareness, improved coordination and information sharing in order to support competent actions by a range of emergency response actors. To accomplish such ability, information systems must target the needs on both a strategic emergency management level as well as to provide support for the time-critical work by the first responders on an operative level.

Studies of the time-critical, mobile and distributed organization of emergency response have shown the importance of providing infrastructure redundancy (Balachandran, Budka, Chu, Doumi, Kang, 2006), designing information systems that have role-based functionality (Turoff, Chumer, Van de Walle, Yao, 2004) and the needs to provide integration between the mobile and stationary information systems (Meissner, Luckenbach, Risse, Kirste, Kirchner, 2002). However, very few studies focus on the use of information technology from the operative field workers perspective and the challenges of designing information technology use for operative time-critical response work. In a recent article by Marcus and Gasperini (2006) it is shown how the lack of a user perspective had significant negative consequences on the use of an emergency-response system in a police organization.

The design and implementation of information technology for crisis and emergency response must address the field operative challenges of technology use. Failing to do so will not only have consequences on the

field operative level but also reducing the overall value of such technology. As will be outlined in this paper, the major challenge in introducing information technology in field-operative settings is not to make the technology work, but to work with the technology. This paper reports from a study exploring the tension between information technology use and time-criticality in emergency response work.

The research question addressed in this paper is as follows: How could we design IT that complies with the time-critical dimensions of mobile work?

This paper is organized as follows; the next section will presents related work where temporal aspects of information technology use have been studied. Then will the organisational setting be presented and how this study form part of a larger technology change project. The method section will outline the data collection activities and how the data was analysed. The result section will present findings and detailed empirical data. This will be followed by discussion and conclusions.

2 Related work

In the efforts of designing information technology use for time-critical work, a significant focus is required on the temporal aspects of such work in relation to the use of information technology. This section will outline related studies on temporality and information technology use.

Time is a core aspect in human activities. The notion of temporal structuring is one way of conceptualizing time as an enact phenomenon in organizations (Orlikowski & Yates, 2002). In a study of distributed community-based project work it is illustrated how people experience time through the shared temporal structures they enact continuously in their everyday practice (Orlikowski & Yates, 2002). People produce and reproduce a range of temporal structures that shape the temporal rhythm of their ongoing actions. Examples of temporal structures are lunch breaks, project deadlines, and scheduled meetings.

Investigation of temporal rhythms and information searching in medical work has shown that information searching should not be viewed as a separate task from other work activities (Reddy & Dourish, 2002). Instead, information seeking should be understood as an integrated activity that shapes and is shaped by the everyday work of medical workers. By outlining large-scale and fine-grain temporal structures in work the study illustrates how specific tasks are seamless and interwoven part of work and by that shape and is shaped by the work rhythms (Reddy & Dourish, 2002). This means that people create temporal structures as means to accomplish their work and that work produces temporal structures. When people create temporal structures, they become also dependent on them. People shape their own work in relation to the temporal structure, such as working overtime to meet a deadline, or by re-scheduling a deadline. This means that temporal structures in general are negotiable. A study of mobile work among home-care professionals explored how individual, collective and social rhythms provided means to negotiate and modify work schedule in order to cope with expectations and workload (Nilsson & Hertzum, 2005).

The introduction of information technology has impact on the temporal structures in work. A study of temporal effects of information technology on temporal organizing in emergency medical work shows that distinct information technologies have varying effects on temporality of work and that temporal effects of the same information technology vary across work groups (Shen, Yoo, Lyytinen, 2005). Mobile phones are one example of such distinct information technology with its own temporal logic in terms of temporal urgency (Shen, Yoo, Lyytinen, 2005). The study showed that the mobile phone did improve communication between people in the medical setting but also that the mobile phone resulted in a demand of an instant response with limited consideration to the social context. This phenomenon was termed temporal urgency (Shen, Yoo, Lyytinen, 2005) and understood as an effect cause by the technology.

However, rhythms in work affect also the possibilities to use mobile information technology. In a study of police work by Pica & Sorensson (2005) it was shown that the work rhythms had significant impact on the use of mobile information technology. The study of police work also showed that time and safety-critical aspects of such work have consequences on the ability of using information technology. The notion of rhythms of interaction was outlined to conceptualize *"the alternation in intensity of communication through and with mobile technologies as exercised by officers each and every day"* (Pica & Sorensen, 2005). The analysis of rhythms of interaction shows that in intense incident-specific situations, the mobile technology becomes to some extent obtrusive and requires to

instantly transforming from *ready-to-hand* to *in-the-pocket*. The rhythms of work as part of operative police work put important focus on usability issues not commonly found in other use-settings. This problem is partly supported by studies of workforces involved in physical demanding work where interaction with digital artefacts is highly challenging due to the use context (Kristoffersen & Ljungberg, 1999).

In some work domains the temporal structures are negotiable whereas in other work settings, such as in emergency response work and police work. They are more rigid and less negotiable. Such temporal rigidity has been explored in relation to the need to improve accountability in emergency response work (Landgren, 2006). That study outlined four sequential work rhythms, each having its specific temporal structures. The rigidity of these temporal structures presents challenges when designing information technology for emergency response work.

The study outlined in this paper aims to add to the knowledge from studies of information technology and the impact of temporal aspects from specific work settings (Kristoffersen & Ljungberg, 1999; Shen, Yoo, Lyytinen, 2005; Pica & Sorensen, 2005) by using the conceptualisation of emergency response work presented by Landgren (2006). The work rhythms and temporal structures of emergency response work are in this paper used to explore the tension between information technology use and time-criticality in emergency response work.

3 Research setting

The work presented in this paper is part of a larger project involving the study of information technology implementation in a fire & rescue service in a Sweden. This paper covers the initial phase of this project with the main focus on making initial assessments of the challenges of introducing information technology on a field operative level.

The fire & rescue service in focus in this study consists of ten full-time fire stations with about seventy firemen stand-by 24 hours a day as part the operative incident response force. In addition to this, the organization has a command centre with two command operators, one mobile command unit and two incident command support units. The operative units respond to over 6000 alarms annually. The organization has in the last few years started to make attempts to provide information technology to support the operative field units in the response work. As a first step was route navigators installed in the response vehicles to improve the correctness in alarm addresses and route information for the operative units. Lately, a new initiative was formulated focusing on the introduction of mobile devices in order to improve incident specific information in the early phases of operative emergency response.

As a first phase in this initiative the organization formed a joint-project aiming to make initial studies of the challenges in introducing mobile information technology on the operative level. A test team was formed within the organization including one fire crew consisting of six firemen and one fire crew commander. The test team participants' age range was from 28 to 54 years of age and all were employed as full-time firemen. They did not only have different levels of knowledge and competence in using office computer software, but they expressed in initial meetings also different levels of interest in having the work supported by information technology.

In order to study the challenges of mobile information technology in operative work, a low-fidelity prototype was designed. The design was informed by prior ethnographic studies of emergency response work. The prototype had the functionality to mediate information covering incident information and incident location specific information on three different levels including; map, aerial photo over the surroundings and two building blueprints. The information was pulled from a web-server when the user clicked on the links in the web-based user interface. The information delivered by the low-fidelity prototype corresponds to the similar information that commercial systems deliver.

4 Method

The methodological approach adopted in this study was qualitative and inspired by the work on participatory design (Blomberg, J. L., & Henderson, A. 1990) in generally and specifically the use of artefacts as triggers (Mogensen & Trigg, 1992). In this approach, artefacts are used to trigger analysis of the current work practice for the purpose of change (Crabtree, 2003). The focus of the analysis is here shifted from the designed artefact

itself (i.e. the prototype) to the work practice and possible improvements.

The data collection activities in this study are presented below and cover; observation, interviews, workshops and a field exercise.

4.1 Data collection

The author made a series of workplace visits to the particular fire crew prior to introducing the prototype. These visits were organized as full-work day participation which also included following along on alarms. These initial visits provided opportunity to make observations and get a sense of this group's particular work practice and social setting. The observations where documented in field notes and later transcribed. The field notes were analysed and compared with earlier ethnographic studies Hammersley & Atkinson, 1995) of emergency response work (Woods, 1972,; Jiang, Hong, Takayama, Landay, 2004; Landgren, 2005). As part of the workplace visits a series of group interviews were conducted. The objective with the interviews was to investigate the fire crew's assumptions of technology use in relation to the expected benefits. Three semi-structured interviews were conducted as group interviews (Patton, 1990) and each interview session took one hour. All interviews were recorded and transcribed.

Two workshop seminars were organized in order to present and demonstrate the functionality of the prototype. Further, as part of the workshops, the individuals in the fire crew were guided in how to interact with the prototype in a hands-on fashion, using a pre-engagement walkthrough approach. Such approach is intended to introduce the users to a system and provide opportunities to familiarize the users to the core features (Crabtree, A. 2003). The workshops took place in a classroom at the local fire station. The conversations at the workshops were recorded and partially transcribed.

An incident exercise was arranged to study the use of the prototype in the intended use context. The exercise consisted of an automatic alarm at a nearby factory. The focus of the exercise was to provide data to explore aspects of the current work practice that could affect the use of information technology as part of such work. In this field exercise, the fire crew used two tabletpc´s with GSM/GPRS/UMTS internet-connection. The fire crew commander used one device in the front seat position during transportation. The three firemen of the search & rescue unit, sitting in the passenger compartment used the second device. The fire crew commander used the device during the entire exercise whereas the search and rescue unit only used the prototype during the transportation phase. The use of the prototype was recorded using a handheld video camera. The video recording was 17 minutes in length.

4.2 Analysis

The field notes from the participant observation were read several times, transcribed and analysed in relation to prior ethnographic studies of emergency response work. Data from the group interviews and workshop was analysed by organizing the data into a set of themes addressing specific concerns the participants expressed regarding information technology.

The data from the video recording was transcribed and the clips analysed using interaction analysis (Heath & Hindmarsh, 2002). The video was analysed against the work rhythms and temporal structure outlined in the study by Landgren (2006). The analysis was done according to the following procedure. First, the video sequences from the field test was identified and mapped to the corresponding work rhythm in the model. Each sequence was then analysed to verify how the actions taken by the fire crew were corresponding to the temporal structures in the model. In contrast to a real incident, this field test included only the first two work rhythms but all the temporal structures in these rhythms. Second, the sequences from each work rhythm were then analysed to explore the order each information object was viewed and the time spent on each information object. Third, the conversation between the firemen and the fire crew commander was examined by mapping the verbal conversation to the interaction with the prototype.

5 Findings

In the interviews, the fire crew expressed expectations that; the technology could improve their understanding of a particular accident location, the technology could improve the safety of their work, and finally the technology could support rapid intervention. By having access to location specific information directly when the fire crew starts to respond to an emergency, they could become better prepared and by that, be able to make a more competent intervention.

However, in the workshops two major concerns were identified in how to achieve these expected benefits. The fire crew expressed concerns regarding limited interaction time-window and the mobile use of the technology.

Limited interaction time-window: Some firemen expressed concerns that the transportation time to incidents in the local district is too short for the first responding unit to actually having time to use the system. The command centre always makes an effort to dispatch the unit that is understood to have the shortest time for arrival. In most cases, this means that fire crews in one local district most often are the first responders in their home district.

Additional units from neighbouring districts serve as backup or reinforcements. Such units have a longer transportation time and less knowledge about the location. This temporal aspect, which could affect the interaction window presents some concern, as is shown in the following excerpt.

> **Fireman 3:** I am a bit worried... I mean ... I wonder if we will have time to use the system when we have the incident in our own district. Will we be able to use it in such a short time?
>
> **Fire crew commander:** From my point of view, this is the information I am trying to consider and is valuable even when we have the incident in our district.
>
> **Fireman 3:** What I see is that as the first responding unit in our district the time could be too limited but when we go as additional unit in a different district where we have no knowledge about the premises, there on such incidents I see a big value with this information.

The excerpt shows that even if the time-window for interaction is condensed, the fire crew commander argues that the information still is important and has significant value even when the incident is located in their home district. However, this does not reduce the importance to acknowledge the concern of the condensed interaction time-window. A suggestion was made in the discussion that secondary units have in most cases longer distance to the accident location and thereby a longer transportation time. They would therefore be in better position in using and benefit of the information provided by the system. The temporal aspects of the mobilization of units and specifically the temporal structure of transportation affect the opportunities for system use.

Mobile use: The work conducted by a fire crew on the accident location is to a large extent physical work where the use of hand-tools and heavy equipment are primary means to intervene in the emergency. Such physical work presents some limitations on introducing additional devices that the fire crew should or could bring along. Mobile devices mediating incident specific information does not necessary have a place in such work. The following excerpt presents the fire crews reflection on this issue.

> **Fireman 1:** Are we supposed to bring it with us out of the vehicle?
>
> **Fire crew commander:** Should I bring it with me? Honestly, I think...I would access the information enroute to the accident location...if I need more info...then you guys have to start the work and I can stay in the vehicle a minute or so.
>
> **Fireman 2:** It should not be a thing that one must bring along and keep track of.
>
> **Fire crew commander:** I cannot walk around with this too. It is difficult already as it is today with two radio devices and a mobile phone. Sometimes I use the command centre channel when I intended to talk on the local radio channel. This happens. The urgency when we arrive, with people that need my attention and so make it difficult to add an additional device.

The above excerpt illustrates how the fire crew is elaborating on the issue whether the device should be kept in the vehicle or brought along for mobile use on the accident location. The temporal urgency in the initial response work has impact on the ability to bring along the technology. The excerpt shows how the fire crew commander is exploring how the need of using the technology can be negotiated in relation to the need of rapid intervention. What is shown here is a potential conflict between imme-

diate physical presence on the accident site and the value of continued interaction after arrival to the accident site.

5.1 Rapid interaction during mobilization

In the first excerpt from the field exercise, it is shown (Picture 1) how the three firemen in the ISR-unit (Interior Search and Rescue) sitting in the passenger compartment collectively use the prototype. However, only two (F1 & F2) of the three firemen were using the prototype and talking. The third fireman was watching without actively interact in the conversation or the computer interaction. The fire crew commander (FCC) is positioned in the front left seat.

Photos from field experiment

time[1]	actor	conversation	comments / gestures
00:01	**F1:**	There you see where the factory is.	*Looking at a map over the factory and local surroundings.*
00:03	**F2:**	Is it this one?	*pointing with the pen*
00:04	**F1:**	No, this one.	*pointing with finger on screen*
00:04	**F2:**	Okay...	
00:05	**F1:**	Use the aerial view.	*Clicking on a new information tab, accessing an aerial photo*
00:11	**F1:**	I barely see it from here.	
00:13	**F2:**	You enter there.	
00:14	**F1:**	Yes...	
00:16	**F2:**	You can drive in here and turn way there!	
00:19	**F1:**	Use the entry floor...zero level.	
...		*Very loud radio communication over the open-radio channel interrupts the ongoing interaction. Eventually The fire crew commander adjusts the volume and the exercise continues.*	
00:31	**F1:**	You have not receive it, you didn't click.	*Clicking on a new information tab, accessing the building blueprints.*
00:44	**F2:**	It is rotated...the last one is still.	
00.48	**F1:**	No, there is the alarm panel.	*Pointing on screen.*
00:49	**FCC:**	We have radio channel 86 adam.. adam is the radio channel.	
00:58	**F1:**	look here check this...here we enter to the alarm panel...there.	*Pointing on screen.*
01:00	**F2:**	Hmmm.	
01:02	**F1:**	The alarm panel is located five meter that way. At number one approximately.	
01:07	**F2:**	Yes..there somewhere.	*Pointing on screen.*
01:09	**F1:**	There yes.	*Pointing on screen.*
01:14	**F2:**	Alarm panel, it is actually printed here.	*Pointing on screen.*
01:16	**F1:**	It is just behind...just behind the door.	
01:20	**F1:**	Then, it just to check what different types of... one, two, three.	*Counting sections.*

Table: Rapid interaction

[1] Minutes and seconds

The excerpt shows that the firemen spent 1 minute and 20 seconds from the point when they got seated before they had navigated through the information in the prototype, from the schematic overviews and down to the detailed building blueprints. This time-period includes also approximately 20 seconds of interrupting radio traffic, not part of the exercise. They used three different information objects; the map, the aerial photo, and entry level building blueprint. Each new information object was more detailed than the previous potentially extending the length of time spent on each information object. The recording shows that the map was visible approximately 5 seconds, the aerial photo for 20 seconds and the building blueprint more than 35 seconds.

5.2 Conversational resource

In the second excerpt from the field exercise, the fire crew commander asks if the other firemen have looked at any potential risks. Here we see a more collective use of the prototype between the fire crew commander and the rest of the fire crew. The fire crew commander initiates the discussion about risks and one of the firemen starts to read aloud the risk information.

TIME[1]	ACTOR	CONVERSATION	COMMENTS / GESTURES
03:12	FCC:	Have you checked for risks.	
03:13	F1:	Where do you find it?	*Currently looking at the building blueprints*
03:15	FCC:	Object info.	
03:16	F1:	Object info?	
03:17	F2:	We have not read that.	*Clicking on a new information tab, accessing object info and risks.*
03:18	F1:	Lets have a look...so.	
03:22	FCC:	Two storey building.	
03:26	F1:	Lets see.	*Holding the device using left hand for a better reading angle.*
03:27	F2:	Two storey building, three thousand six-hundred square meters, personnel sixty, smoke ventilators.	*Reading loudly.*
03:30	F1		*Clicking on the information tab to access building blueprints.*
03:33	F1:	Smoke ventilators...there is a room...there a room with hazard material.	

Table: Conversational resource

[1] Minutes and seconds

The above excerpt shows how the textual content in the prototype results in an initiative to read aloud in order to share the information with the entire fire crew. The textual information includes both building specific properties as well information regarding potential hazard material. Information understood as particular important by the fire crew.

The excerpt also shows how the fire crew commander asks the firemen if they have seen the location of the alarm panel. The location of the alarm panel is the prioritized arrival point in cases of automatic-fire alarms, which was the case in this exercise alarm. The excerpt shows how the information mediated by the prototype works as a conversational resource in order to reach an understanding of the location. The fire crew commander has access to the same information as the firemen but still we see verbal communication where references are made to the information mediated by the prototype in order to make sense of the specific incident location. The above conversations also indicate that the firemen and the fire crew commander on several occasions were using different information objects that required adjustment in order to see the same information objects.

The time spent on interacting with the prototype and talking about building specific properties was around 45 seconds. During this time the

firemen used a three-step sequence, starting with building blueprints, switching to building info and the switching back to building blueprints.

5.3 Situational assessment in initial intervention

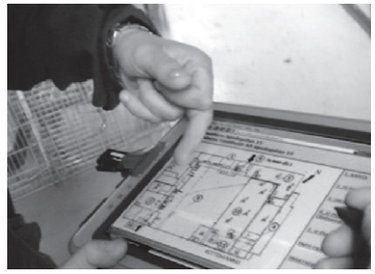
In the third excerpt from the field exercise, the fire crew commander is involved in a conversation with a representative (CR) from the company as is shown in picture 2. Information mediated by the prototype is here used to support the fire crew commander's initial situation assessment.

TIME [1]	ACTOR	CONVERSATION	COMMENTS/GESTURES	PICTURE
09:14	FCC:	What sort of things do you have up there?	Pointing at the building blueprint on the screen.	A
09:16		*Radio call from the firemen informing that they are at the top floor.*		
09:25	CR:	It is the location to count all the garments		
09:29	FCC:	Garments.		
09:30	CR:	It is a loading station up there and we send it all down through pipes on the other side of that wall.	Pointing on screen.	B
09:36	FCC:	Okay.		
09:39	FCC:	Where do you.... where do you store the hazardous material...it says you have 2000 litres.	Switching view to objectinfo.	
09:50	CR:	Yepp, it is stored in the room thirty meters down this hall on the right side.	Pointing with his hand down the corridor.	

Table: Situational assessment

[1] *Minutes and seconds*

Picture A



Picture B

The excerpt shows how the prototype is providing means to make the situation assessment based on information covering both building layout and hazard material. The company representative provides location specific knowledge, which helps the fire crew commander in understanding not only the building specific structural properties but also the very activities taking place in the factory. The conversation in this excerpts shows how the initial question addresses the location of the triggered smoke sensor and how the conversation later is focused on the location of the hazard material stored on the ground level.

6 Discussion

The findings from the field exercise indicate that the prototype was successful as a triggering artefact in exploring the challenges in using information technology in emergency response work.

The results from this study show that the initial concerns regarding *interaction time-window* to a large extent did not obstruct the situated use. The technology did not alter the work rhythm or imposed new temporal structures as in the case with mobile phone use in the medical setting (Shen, Z., Yoo, Y., & Lyytinen, K. (2005). In contrast to this, it was here shown how the prototype supported the fire crew to make sense of the accident location, and did not add tasks that conflicted with the work at hand.

The interaction with the prototype was rapid and focused. The previously concerns regarding potential limitations of the interaction-time window were not evident in the result from the evaluation. The fire crew focused in the first interaction cycle on improving their understanding of the physical dimensions of the location and building. In the second interac-

tion-cycle, focus was put on risks and hazard material. The field exercise shows that the two interaction cycles were fairly short but still delivered resources for the collective verbal conversations. Further, the mobility of the technology became a resource for the fire crew commander in the situation assessment activity. The problem of making place for the technology (Kristoffersen, S. & Ljungberg, F.1999) was not evident. Rather the technology mediated specific resources for the conversation between the fire crew commander and the company representative.

The tension between information technology use and temporal aspects in time-critical work is more complicated than just claiming that information technology have a temporal impact. The results from the field exercise are interesting in relation to the two major concerns expressed by the fire crew in the workshops prior to the field exercise. In the workshop, the fire crew expressed concerns whether or not there could be a mandatory requirement to use the technology. The situated use in the field exercise shows that it is rather a question of need to use. The excerpts show how the fire crew made use of the technology in relation to their current situation. The results of this study indicate that the design of information technology for time-critical work should avoid features that could lead to temporal urgency and thereby obstruct the work. Such features are highly related to mandatory tasks of using the supporting information technology.

The findings in this paper are based on data of only one field exercise. One could argue that there is a great difference between a field exercise and a 'real' incident. This is true to some extent, especially on an incident where a fire crew arrives to a factory that is on fire. However, in many small-scale incidents, there are no clear visual signs of the accident and significant time is spent on finding the emergency when arrived to the incident location. The field exercise presented in this paper is therefore to a large extent a good representation of what could take place on a real incident. The true complexity of a full-scale emergency response operation is not accounted for in this study, which to some extent limits this study in respect to the complexity of several involved actors (Grudin, 1988) that would have been the case in a real incident.

This paper contributes to previous research by further exploring the inter-related relationship between temporal aspects of work practice and the use of information technology. Previous studies have shown that information technology have impact on the temporal aspects (Shen, Yoo, Lyytinen, 2005), whereas in this paper it is shown how technology can be designed and introduced to comply with these temporal aspects.

The results presented in this paper will provide input for the continual work with the local fire and rescue services. The results cannot easily be generalized, across domains or organizations, especially against the limitations of this study. However, the descriptions of the reflections and situated use of information technology could provide insights to better address the complexity of designing information technology for time-critical work settings. According to Guba & Lincoln (1989), instead of striving for generalizability, studies based on an interpretative approach could instead aim to *"facilitate transferability judgments on the part of others who may whish to apply the study to their own situations"* (Guba & Lincoln, 1989, p242)..

7 Conclusion

This paper has explored the tension between information technology use and time-criticality in emergency response work. The study outlined in this paper is part of initial assessment activities in of the challenges in using information technology in field operative emergency response. The work presented in this paper is part of a larger project involving the study of information technology implementation in a fire & rescue service in a county. However, this paper covers the initial phase of this project with the main focus on making initial assessments of the challenges of introducing information technology on a field operative level. The results presented in this paper contributes to research and practice by showing that information technology use could support emergency response work without having a temporal impact such as temporal urgency caused by the technology. There is a need to balance the tension between information technology and time-criticality of work, by providing a design that avoids temporal urgency caused by the technology.

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References

Balachandran, K., Budka, K.C., Chu, T.P., Doumi, T.L., Kang, J.H. (2006). "Mobile responder communication networks for public safety." Communications Magazine, IEEE 44(1): 56-64.

Blomberg, J. L., & Henderson, A. (1990). Reflections on participatory design: lessons from the trillium experience. Proceedings of the SIGCHI conference on Human factors in computing systems: Empowering people, Seattle, Washington, United States.

Crabtree, A. (2003). Designing Collaborative Systems. London: Springer-Verlag.

Grudin, J (1988). Why CSCW-Applications Fail: Problems in the Design and Evaluation of Organizational Interfaces. Proceedings of the Conference on Computers-Supported Cooperative Work.

Guba, E. G. and Y. S. Lincoln (1989). Fourth Generation Evaluation. London, United Kingdom, SAGE Publications.

Hammersley, M., & Atkinson, P. (1995). Ethnography (second ed.). London: Routledge.

Heath, C. & Hindmarsh, J. (2002). Analysing Interaction: Video, ethnography and situated conduct. Qualitative Research in Action. T. May. London, Sage: 99-121.

Jiang, X., Hong, J., Takayama, L., Landay, J. (2004). Ubiquitous computing for firefighters: field studies and prototypes of large displays for incident command. 2004 conference on Human factors in computing systems, Vienna, Austria, ACM Press New York, NY, USA.

Kristoffersen, S. and F. Ljungberg (1999). "Making place" to make IT work: empirical explorations of HCI for mobile CSCW. The international ACM SIGGROUP conference on Supporting group work, Phoenix, Arizona, United States, ACM Press New York, NY, USA.

Landgren, J. (2005). Supporting fire crew sensemaking enroute to an incident. International Journal of Emergency Management. Inderscience Publishers, 2:3

Landgren, J. (2006). Making Action Visible In Time-Critical Work. Proceedings of the SIGCHI conference on Human Factors in computing systems (CHI2006). Montreal, Quebec, Canada. ACM Press.

Marcus, A. & Gasperini, J. (2006). Almost dead on arrival: a case study of non-user-centered design for a police emergency-response system." Interactions 13(5).

Meissner, A., Luckenbach, T., Risse, T., Kirste, T., Kirchneret, H. (2002). Design Challenges for an Integrated Disaster Management Communication and Information System The First IEEE Workshop on Disaster Recovery Networks (DIREN 2002), New York City.

Mogensen, P., & Trigg, R. H. (1992). Artefacts as triggers for participatory design. Proceedings of the 1992 Participatory Design Conference, Boston: Computer Professionals for Social Responsibility.

Nilsson, M. & Hertzum, M. (2005). Negotiated Rhytms of Mobile Work: Time, Place and Work Schedules. GROUP'05, Sanibel Islands, Florida, USA, ACM.

Orlikowski, W. J. and Yates, J. (2002). It's about time: Temporal structuring in Organizations, Organizational Science, 13:6, 684 -700.

Patton, M. Q. (1990). Qualitative Evaluation and Research Methods. London, United Kingdom, SAGE Publications.

Reddy, M. and Dourish, P. (2002). A finger on the pulse: temporal rhythms and information seeking in medical work. In Proc CSCW2002, p 344 – 353, ACM Press

Shen, Z., Yoo, Y., & Lyytinen, K. (2005). Temporal Implications of Information Technology for Work Practice: Organizing in and for Time in Emergency Department. Sprouts: Working Papers on information Environments, Systems and Organisations, 5(2): 88-101.

Pica, D. & Sorensen, C. (2005). Tales from the police: Rhythms of interaction with mobile technologies. Information and Organization, 15(2): 125-149.

Turoff, M., Chumer, M,. Van de Walle, B,. Yao, X. (2004). "The Design of a Dynamic Emergency Response Management Information Systems (DERMIS)." Journal of Information Technology Theory and Application 5(4).

Woods, J. (1972). Fire Calls: Ethnography of Fire Fighters. The Cultural Experience: Ethnography in Complex Society. J. p. Spradley and D. W. McCurdy. Palo Alto, Science Research Associates: 221-239.

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