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INVESTIGATING THE TENSION BETWEEN INFORMATION TECHNOLOGY USE AND EMERGENCY RESPONSE WORK

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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 information technology use. 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 (ie 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 was 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 start 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 on 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. This means in most cases 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 is still 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.

> Fireman1: "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"
>
> Fireman2: "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 immediate 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.

Picture 1

Time	**Actor**	**Conversation, translated to English**	**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!	Pointing on screen
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

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	**Actor**	**Conversation, translated to English**	**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	

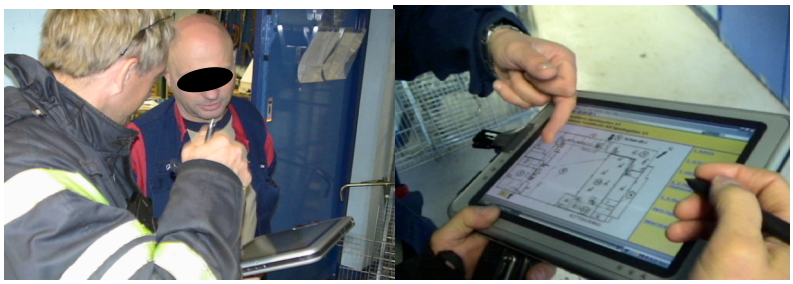
The above excerpt shows how the textual content in the prototype results in an initiative to read aloud in order to share the information with the entire fire crew. The textual information includes both building specific properties as well information regarding potential hazard material. Information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



Picture 2

Time	Actor	Conversation, translated to English	Comments / Gestures
09:14	FCC:	What sort of things do you have up there?	Pointing to the building blueprint on the screen
09:16		*Radion 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 hazard...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

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 interaction-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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