Generic functionality in user interfaces for emergency response

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ABSTRACT
In this paper we use findings from a number of empirical studies involving different emergency response actors to identify shared or overlapping needs for user interfaces functionality. By analyzing the findings from these studies, we have identified 11 categories of functionality supporting shared needs, including functionality for handling incident information, logging facilities, and functionality for managing human resources and equipment. After presenting our research method, we give an overview of the identified categories of shared functionality. We also describe one of the categories, namely resource management, in some more detail including giving examples of concrete user interface functionality. We have validated the conclusions of our findings through observations and interviews in a training exercise. The validation supported our prediction that the exercise would not reveal major additional categories of functionality, and it also supplemented the earlier findings regarding which actors that need which categories of functionality. We conclude by discussing pros and cons of using generic solutions supporting shared functionality across emergency response actors.

Author Keywords
Emergency response; Generic user interface components; Mobile HCI

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

INTRODUCTION
Emergency response operations may be viewed as variations on certain themes. Response taking place at or close to the scene of an incident (i.e. on tactical level) involves a varying number of actors. These may include governmental agencies like the police, ambulance and fire services, as well as non-governmental organizations (NGOs) including local industrial defences and voluntary ones like the Red Cross. Despite this, the involved agencies are often the same and always a combination of a limited set. A simple operation may involve only one actor, while large and complex operations may involve tens of different actors. Despite this, the police are involved in almost all operations. The involvement and role of the different actors depend on the type of operation (like accidents, fires, search and rescue, avalanche, earthquake and tsunami), as well as the size, location, extent and duration of the operation (Chen et al, 2008, Hill, 2010).

Despite a large variation space, the different actors have well-defined roles and responsibilities. Some of the roles and responsibilities are independent of the type operation, but some agencies like the fire department may have different responsibilities depending on characteristics of the operation. E.g. in a traffic accident, their role will vary depending of whether there is a fire or not, and whether there are humans wedged in the car. Despite this, the set of possible tasks in a given type of operation is restricted, and a number of tasks are identical or very similar across both type of operations and different actors.

A large degree of variation indicates that ICT solutions supporting mobile users should be tailored to the specific needs and variations. This view is opposed by an important issue pointed out by our informants in a number of cases, namely that any possible ICT support for emergency response must scale between operation types and operations of different size and complexity. I.e. any support tool that is not used in the day-to-day operations will be of limited use in rare, large and more complex operations, as the emergency responders will not have the time to fumble in order to figure out how the tool works. Furthermore, the similarities in tasks within each actor as well as across actors indicate that common solutions that scale between different kinds of operations and offer tailoring possibilities might be the best option. In this paper we investigate which shared and overlapping needs for user interface functionality such solutions must support, based on findings from a number of empirical studies.

In the next section we present our research method. Then we outline 11 categories of functionality supporting shared needs, followed by a more detailed presentation of one of these categories, namely *functionality for resource management* (we refer to Nilsson and Stølen (2011)) for similar presentations of the other categories). After that we present and discuss the findings from our validation activities. Then we compare these findings with the findings in the studies upon which the identification of 11 categories are based, and summarize the findings in all our studies. After presenting and comparing related work to our results, we conclude and give the direction of our future research.

RESEARCH METHOD
The overall research question driving the work presented in this paper is whether it makes sense to classify the common needs between the actors involved in emergency

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response into categories of functionality, and to provide such a classification. In addressing this research question, we have followed a step-wise process as described below.

Step 1: Empirical studies of emergency response work

In this step we conducted five studies:

- Study A: Training exercise within avalanche rescuing organized by the Norwegian Red Cross (Nilsson, 2010a, Nilsson and Brændland, 2009). In this study we performed observations, interviews, an expert evaluation of an existing support tool, and attended theoretical education.
- Study B: Training exercise of rescuing operation involving fire in a ship storing gas, being conducted by the National Police Directorate in Norway (Nilsson, 2010b). In this study we performed observations and shadowing.
- Study C: Interviews with experienced local leaders and smoke divers in fire service (Nilsson, 2010c).
- Study D: Interview with experienced local leaders in the police (Joshi, 2011).
- Study E: Interview with experienced local leaders in ambulance service (Nilsson and Stølen, 2011).

Step 2: Analysis of findings from Step 1

In this step we aggregated the findings from Step 1 to identify possible categories of functionality shared by at least two emergency response actors.

Step 3: Hypothesis about generality

Once the categories had been identified and characterized, we formulated the hypothesis that the sum of functionality in these categories covers the needs in medium size operations within the emergency response field in Norway. By medium size operations we exclude simple "everyday" operations involving a small number of casualties and emergency response personnel (typically a small traffic accident), as well as really big, seldom occurring, and long-lasting operations like responses to terrorist attacks, earthquakes, tsunami, etc. The reason for restricting the validity of the hypothesis to Norway is that Study A-E as well as the validation all were conducted in Norway.

Step 4: Validation

In order to test the hypothesis from Step 3, we predicted that the classification from Step 2 would be reflected also in the following study:

- Study F: Training exercise focusing on an accident in a location involving special challenges for access and transportation of victims organized by the ambulance service. In this study we performed observations, shadowing and interviews (Nilsson and Stølen, 2011).

The interviews conducted in Study F were aimed at obtaining supplementary information regarding the exercise and more general information with respect to the topic presented in this paper. Two out of three interviews had a different focus than categories of functionality in support tool, but included a minor section addressing the topic of this paper.

Step 5: Analysis of findings from Step 4

The findings from Step 4 were analyzed by comparing the actual findings with the prediction from Step 4.

Actors involved in the empirical studies

All our studies involved one or more emergency response actor. In Table 1, we present which actors were involved in which study, and how information describing their needs were collected.

	Police	*Fire*	*Amb.*	*Red Cross*	*Other*
Study A	Obs.			Obs./Int.	Obs.
Study B	Shad.	Obs.	Obs.		None
Study C		Int.			
Study D	Int.				
Study E			Int.		
Study F	Shad. Int.	Obs.	Obs. Int.		Obs.

Table 1. Actors involved in the studies.

The following abbreviations are used in the table:

Obs.: Observations

Int.: Interviews

Shad.: Shadowing

The “other” actors involved in Study A were military personnel, The Airborne Ambulance Service and The Norwegian Joint Rescue Coordination Centre. In Study B the local industrial defence and The Coast Guard were involved, but for practical reasons, information was not collected from these actors. In Study F, the “other” actors were The Norwegian Joint Rescue Coordination Centre and the local industrial defence.

Methods applied in individual studies

In Study A, B and F we used observation (Crang and Cook, 2007 (Ch. 3 and 4)) of different actors. In Study B and F, we combined the observations with shadowing. In all studies except Study B, we also interviewed local leaders (Crang and Cook, 2007 (Ch. 5)). When doing observations and shadowing, notes taking (Crang and Cook, 2007 (Ch. 5)) in combination with photos and video recording were used for documenting the findings. When interviewing, notes taking was used for documentation in all studies, in combination with audio recording in Study C, E and F. All audio recordings from the interviews have been transcribed. The expert evaluation performed in Study A was a group-based expert walkthrough (Følstad, 2007). In the analyses in

Step 2 and 5, coding (Crang and Cook, 2007 (Ch. 8)) was used.

CLASSIFICATION INTO 11 CATEGORIES

In this section we present a set of 11 categories of functionality identified in Step 2. The categories emerged as a result of analyzing tasks performed by local leaders, and the information involved in performing these tasks (and thus the information that is needed by an ICT based system that supports the tasks).

Operational picture

By this we mean functionality supporting definition of an operational area (Büscher and Mogensen, 2007), i.e. the main geographical area in which an operation takes place, as well as functionality supporting the building of an (common) operational picture (Kuusisto et al, 2005). The need for managing an operational area and maintaining an operational picture is most evident for the police and the NGOs. A common operational picture is by nature shared by most actors.

Our findings in studies involving the police show that maintaining information about the location of the incident as well as the location of the control post and local bases are important. A map-based representation is most appropriate. An operational area may include different zones, with varying access restrictions and varying needs for keeping detailed information about available resources.

Our findings in studies involving the NGOs show similar needs as for the police, with less focus on access restrictions but more focus on observations and findings in the operational area. In geographically restricted operations like an avalanche rescuing, establishing the extent of the operational area automatically using GPS tracking is a possible solution making this more efficient and accurate than drawing it manually in a map.

Incident details

By this we mean functionality supporting the maintenance of information about objects and persons involved in an incident (Chen et al, 2008).

Needs for this type of functionality have been revealed in our studies involving the police, ambulance services and the NGOs. The police need to handle information about casualties, missing persons, possible gas leaks, etc., while the ambulance service has a special need for keeping overview of casualties, including their locational status (at the location of the incident, at a local base for injured patients, or taken to hospital). The Red Cross specifically often operate with an hypothesis about the incident, which may include what has probably happened, the number of missing persons, etc., as well as location of findings, which may be reported automatically using GPS or other location sensors.

Logging

By this we mean functionality supporting the tasks of keeping a log of the incidents and events during an emergency response (Chittaro et al, 2007).

All emergency response actors keep some sort of log of their activities, but the need for supporting a logging task has been accentuated by the police and ambulance service. Logging may be needed for legal reasons, for evaluating the response, as well as for later investigation. In addition, the police also stated that it would be useful to be able take a snapshot of the current situation, not only as part of a log, but also to use for handover to a new incident commander if the operation is long-lasting. Ambulance services are obliged to write a medical record for all patients involved in an incident. This task could be made more efficient if information that is being logged manually or automatically is easily available when writing the records. They also see a need for recording live pictures during an operation as documentation.

Information services

By this we mean functionality for accessing services providing useful information during an operation (Turoff et al, 2004).

Needs for this type of functionality have been revealed in our studies involving the police, ambulance and fire services. The police need a variety of information, like weather forecast, information about dangerous substances, access to the police's centralized systems, as well as check lists for different types of operations. There is also a need for having information from different sources visualized together. Fire services share the need for information about dangerous substances and weather forecasts, but also have a special need for accessing pre-collected information about special buildings and other objects that may be on fire. The information that is pre-collected includes evacuation plans, number of people usually present in the building, as well as gas and other dangerous substances being stored. Ambulance services may need to access more information than the one that is usually available about a patient in an ambulance today, like the medical record, information about allergies, and chronic diseases, as well as getting an overview of capacity for doing different types of treatment in hospitals nearby.

Resource management

By this we mean functionality supporting management of resources, i.e. personnel and equipment available among the different emergency response actors (Pottebaum et al, 2007, Joshi, 2011). Keeping track of the location of the resources is considered essential, as well as how the resources are allocated to different tasks. In addition to handling own resources, there is also a need to know e.g. location of the key personnel working for other actors. In some special operations, like avalanche rescue, it is also essential to keep accurate track of who is in- or outside the operational area. Resource management may also include information about personnel available for communication.

All emergency response actors need support for managing resources. The need has been most evident in the police. The fire services focus mostly on location, while the ambulance services have particular attention on allocation. NGOs have similar needs as the police, but do not have the same need to locate other personnel than their own. This category of generic functionality is presented in more detail in Section 4.

Actions and plans

By this we mean functionality supporting planning and accomplishing of the tasks and actions performed by the emergency response personnel (Humayoun et al, 2009). Having plans and tasks explicit in the operations close to the scene of the incident is not so common in our findings, but in the cases where plans and tasks are managed by a higher level of operation, having access to this information is important, including receiving tasks and reporting progress/fulfilment of the tasks.

The Red Cross is the only actor that has expressed an explicit need for making plans and issuing tasks by an incident commander present at the scene of an incident. The need for receiving tasks and reporting to a central is most evident in our findings from the police.

Transmission

By this we mean functionality for transmitting live pictures either between personnel at the scene of an incident, between this personnel and some centralized body (Bergstrand and Landgren, 2009), as well as from special equipment (like a helicopter) to personnel at different levels of an emergency operation.

Needs for this type of functionality have been revealed in our studies involving the police, ambulance and fire services. The police focus on the need for transmission from special equipment. The fire services focus on transmitting between personnel at the scene of an incident (e.g. live pictures from an infrared camera). The ambulance services focus on transmission to a centralized body and the hospital that is about to receive a patient to facilitate preparation for treatment.

Monitoring

By this we mean functionality for monitoring either personnel or victims of an incident. Such monitoring involves utilizing various sensors being attached to the personnel/victims (Martı et al, 2009, Jiang et al, 2004a).

Needs for this type of functionality have been revealed in our studies involving ambulance and fire services. Fire services focus on equipment for monitoring the health conditions of fire fighters/smoke divers, while ambulance services focus on equipment for monitoring victims. A possible light-weight solution for ambulance services is having the paper-based tags used for labelling the patients replaced by electronic tags, possibly with transmission facilities, but without sensors monitoring the health conditions.

Automatic reasoning

By this we mean functionality for automatically obtaining status for certain aspects regarding an operation. Examples of this are keeping track of which areas that have been covered in a search and rescue operation, and functionality for performing (semi)automated analyses based on available information that may help the users in making better decisions (Nilsson and Stølen, 2010). It may also include special visualization of changes in status information and directional support for users moving around as part of solving a task (Bernoulli, 2010).

Needs for this type of functionality have been revealed in our studies involving fire services, NGOs, and the police. Fire services have the need for using sensor data for deducing which parts of a building that have been cleared (i.e. the fire has been put out and it has been searched for possible missing persons). Voluntary NGOs would benefit from obtaining information about which areas that are covered in a search and rescue operation. In geographically disperse operations, like searching for a missing person, GPS tracking on the search personnel may be utilized for drawing a coverage map automatically. In operations that are geographically more restricted, like an avalanche operation, a combination of GPS and movement sensors on the search poles may be used for a making a detailed map of which parts of the search area that have been covered, as well as how many times and in which direction the searches have been performed. The police may benefit from similar functionality as outline for the NGOs, but also more specialized analyses like a parameterized probability function for where a missing person may be located.

Communication management

By this we mean functionality aiding users in using existing communication mechanisms (Dunn et al, 2002). Thus, it does not involve the actual mechanisms used for communication, which today is dominated by special purpose radios (like TETRA (ETSI, 2009)) as well as mobile phones. According to our studies, the latter are used extensively for in-depth or other one-to-one communication, particularly communication that is considered inappropriate to perform using shared radio channels.

Needs for this type of functionality have been articulated by the ambulance and fire services, where certain local leaders use two or more radios for communicating with different peers or agencies. The ambulance services stated a special need for functionality for easy switching between different communication partners.

Special interaction mechanisms

The user situation for on-site personnel in emergency response is characterized by requiring a high degree of attention while solving the tasks (Streefkerk et al, 2006, Nilsson and Stølen, 2010). This poses special requirements to the design of the user interfaces (Nilsson and Stølen, 2010), which may include utilizing designated hardware buttons, multimodal user interfaces (Cohen and McGee, 2004) as well as augmented reality techniques (Fröhlich et al, 2007). This category differs from the ones above in the way that it represents a kind of meta-functionality that may be used as a way of interacting with arbitrary components that are suited for such interaction. Needs for this type of user interface mechanisms have been articulated by the ambulance and fire services.

Summary of the 11 categories of functionality

As part of the analysis resulting in the descriptions of the categories just presented, we also categorized how much focus the involved actors have on each category (i.e. on the tasks and information needs that the categories of functionality are to support), and to which degree the needs are supported by the solutions used by the actors today. By solution in this context, we include existing ICT equipment, applications and services, non-ICT support (like pen and pencil), as well as managing the tasks without using any support tools at all. The result of this categorization is presented in Table 2. In the table, the rows represent the categories of functionality, while the columns represent the involved actors. The cells in the table are coded with two values. The colours represent how much focus the actors have on each category in a given agency using this scale:

Strong focus	Moderate focus	No or very limited focus

For the cells where the focus is moderate or strong, we have marked the cells where we have found clear signs of unsupported needs with an asterisk (‘*’).

	a. Pol.	*b. Fire*	*c. Amb.*	*d. Red Cross*
1. Operat. pict.	*			*
2. Incident det.	*		*	*
3. Logging			*	
4. Inf. services	*		*	
5. Res. manag.	*			*
6. Actions & pl.				*
7. Transm.		*	*	
8. Monitoring		*	*	
9. Autom. reas.	*	*		*
10. Comm. m.			*	
11. Sp. int. m.		*	*	

Table 2. Summary of needs from Study A-E.

EXAMPLE: FUNCTIONALITY FOR RESOURCE MANAGEMENT

The presentation in the previous section showed that resource management is needed in all emergency response actors studied in our empirical work. As outlined above, resource management involves managing personnel and equipment, and there are needs for managing both location and allocation (Pottebaum et al, 2007, Nilsson, 2010b, Joshi, 2011). In addition to managing the resources connected to a given actor, the actor may also need to know about which resources are available from the other actors, including their location and how they may be contacted.

A given actor normally knows which resources the actor manages. This means that basic information about the resources will normally be available electronically when an operation commences. This again means that lists of resources may be presented to users without anyone having to enter any information, and that identifying a specific resource that should be located, allocated or reallocated may be done by selecting information that is presented, typically in a map- or list-based user interface. Some special operations, like a search and rescue or an avalanche rescuing operation, may require large amounts of resource. Such operations may thus involve resources from other actors, including voluntary personnel of which very little information is known in advance. Managing such personnel adds special challenges, as basic information needs to be registered, among other to maintain the safety of such personnel.

Keeping track of resources is the main task within resource management. This involves having information about the location of resources and to which rescuing tasks the resources are allocated, as well as performing allocation and reallocation of resources. This is typically a task that is performed in close cooperation with the alarm central or a central staff, and where services keeping information about resources are important. Automatic tracking of resources (e.g. by using GPS tracking) is an important aid for keeping an overview of locations. When performing this task, the user needs to know about issues like status and owner of resources. The priority of allocations is important when scarce resources are to be (re)allocated. Also, there is a difference between how human resources (personnel) and equipment are handled. Furthermore, resources may be categorized in at least three groups with respect to availability, i.e. (i) resources that are known, but not available (need to be mobilized or requested), (ii) resources that are available, but not allocated, and (iii) resources that are available and allocated.

Figures 1 and 2 (from Joshi, 2011) show screen shots from a prototype of a mobile phone application supporting locating, allocating and reallocating resources. Figure 1 shows each resource as an icon on a map-based user interface. The visualization uses a combination of colour and symbols to visualize different properties of the resources (including type and subtype as well as allocation and priority). The prototype also offers filtering mechanisms to ease identification of special resources and provides details about the resources in floating pop-up panes. Figure 2 shows dialogs used for allocating resources. The leftmost dialog shows the main types of equipment (vehicles, sensors and auxiliary equipment). Each type may be expanded (as shown in the middle dialog) to show the subtypes of equipment. These subtypes may be expanded further (not shown in the figure) to show the individual resources. The individual resources may be selected in order to allocate the resource to a specific task (as shown in the rightmost dialog). Allocation involves setting a priority on the allocation. Completion of the allocation usually involves specifying a location on the map.

Figure 1. Location of resources showed in map.

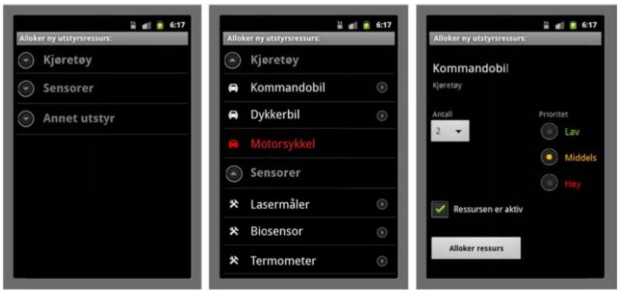

Figure 2. Details of resources and their allocation

VALIDATION OF THE CLASSIFICATION INTO 11 CATEGORIES

Hypothesis and prediction

Our overall hypothesis is that the needs for common functionality in medium size operations within the emergency response field in Norway are covered by the sum of functionality of the 11 categories presented in Section 3. In order to test this hypothesis, we conducted a further study at the *Urban rescue* training exercise (Study F in Section 2), where we made the following prediction:

- The exercise will not reveal major categories of functionality in addition to the 11 described in Section 3.

As the findings in Study A-E each identified focus on and uncovered needs in only a subset of the 11 categories, it was reasonable to assume that the same would apply to Study F. Thus, it was not natural to predict that we would observe exactly the same focus and needs as in any of the individual prior studies, nor as the sum of the findings in Study A-E, but rather that the needs in Study F are a subset of or overlap with this sum.

Findings from observations in Study F

The findings from our observations combined with information presented during the debriefing session after the exercise are presented in Table 3. The table uses the same colour and markings as Table 2.

	a. Police	*b. Fire*	*c. Ambulance*
1. Operat. pict.	*		*
2. Incident det.	*		*
3. Logging			
4. Inf. services	*		
5. Res. manag.			
6. Actions & pl.			
7. Transm.		*	*
8. Monitoring			
9. Autom. reas.			
10. Comm. m.			*
11. Sp. int. m.			

Table 3. Observed focus on the different categories.

E.g., this means that we observed that both the police and the ambulance service had a strong focus and unsupported needs for maintaining an operational picture, while the ambulance services had moderate focus on resource management, but that their needs were supported by existing solutions.

Findings in interviews in Study F

The findings from the interviews with local leaders from the police and ambulance services are presented in Table 4 (as we did not interview representatives from the fire department, the column for this agency is removed). The table uses the same colour and similar markings as Table 2 and 3. As the interviews covered both the interviewees' experiences during the exercise and their experiences and needs in general, there are some categories of functionality where they did not identify unsupported needs during the exercise, but expressed that they experience unsupported needs in other operations and situations. For such categories, the asterisks are put in parenthesis.

	a. Police	*c. Ambulance*
1. Operat. picture	*	
2. Incident details	(*)	(*)
3. Logging		
4. Inf. services	(*)	
5. Resource management	(*)	
6. Actions & plans		
7. Transm.	*	*
8. Monitoring		
9. Autom. reason.		
10. Comm. m.	(*)	
11. Sp. int. m.		

Table 4. Stated focus on the different categories.

E.g., this means that the interviews show that both the police and the ambulance service had a moderate focus and unsupported needs for transmission, but that the police had a strong focus supported by existing solutions for managing incident details. Regarding the latter, at least one of the interviewees expressed that they have experienced unsupported needs in other operations.

Discussion

The validation through Study F sought to check our overall hypothesis through comparing the findings in this study with the prediction presented in Section 5.1. The hypothesis is that the need for common functionality in medium size operations within the emergency response field in Norway are covered by the sum of functionality of the 11 categories presented in Section 3. Before discussing this, we need to point out that *Urban rescue* training exercise fulfils the requirements in the hypothesis, by being of medium size and taking place in Norway (Nilsson and Stølen, 2011).

The detailed findings presented above revealed focus on eight of the 11 identified categories of functionality by at least one of the agencies that we observed. For all these agencies, unsupported needs were revealed for from one up to six of the categories of functionality. More importantly, neither the observations, the interviews, nor the debriefing session revealed any clear indications of needs for any additional categories of functionality. We actively sought for such indications, especially during the observations and interviews. This means that the findings in Study F support the prediction presented in Section 5.1. Thus we may conclude that these findings also strengthen the hypothesis. Although not part of the prediction, it is important to stress that Study F indeed showed clear indications of focus on and unsupported needs for a majority of the 11 categories of functionality. This is important as one may say that finding no focus or unsupported needs also would be covered by the prediction.

As indicated in Section 2.3, we restrict the hypothesis to medium size operations in Norway. As all the studies are conducted in Norway, this is a natural restriction. Despite this, both the literature and other research that we are currently performing (BRIDGE project, 2011) indicate that the categories apply also more generally. So far, these indications show that generalizing outside Norway is safer than generalizing on size of operation. Regarding the latter, scaling down is not problematic with regards to generality, but maybe not with regards to usefulness, as a number of the categories of functionality may be viewed as overkill for supporting small, "everyday" operations. Scaling up is more problematic, as recent incidents have shown that e.g. functionality for collecting information from and interacting with the public (which is not part of our 11 categories) is important in large scale, complex and/or long lasting operations (Palen et al., 2007).

One may claim that the classification into categories to some extent is arbitrary. Such a claim is however not supported by the interviews in Study F. They addressed the 11 categories explicitly, and the interviewees did not comment or object to the division into the given categories. To address this more systematically, empirical studies using implementation of components realizing the categories of functionality are needed.

ALL STUDIES VIEWED TOGETHER

Comparing the findings in Study F with the findings in Study A-E

If we compare the cell colours in Table 3 and 4 with the corresponding colours in Table 2, there are a number of cells where the colours are darker in the findings from Study F than the summary from Study A-E, like the stronger focus on actions and plans by the police (cell (a,6)) and the stronger focus on operational picture by the fire services (cell (b,1)). Generally, these findings support the overall approach, and it shows that the identified categories are useful.

There are also a number of cases where the colours in Table 3 and 4 are lighter than in Table 2, like the lower focus on logging by the ambulance service (call (c,3)). The natural interpretation of this is that focus on the different categories of functionality will indeed vary in different observations, based on nature, size and duration of incident, number of actors involved, number of persons involved from the different actors, as well as the geographical extent of the operation (Nilsson and Stølen, 2011). This fits with the findings in Study A-E, where there indeed are differences with regards to how much focus each actor has on a given category (i.e. the cell colours) in each of the individual studies.

Addressing the asterisks, i.e. whether the needs are supported by the solutions available today or not (the latter indicated by an asterisk), there are some cases where the observation in Study F (Table 3) show that the solutions available are not sufficient in cases where this was not found in Study A-E (Table 2). One example of the is the indication of unsupported needs for managing an operational picture for the ambulance service (cell (c,1)). Like with the colours discussed above, this also supports the overall approach, and indicates that the categories are useful.

There are also some cases where the observations in Study F (Table 3) do not replicate the findings that the existing solutions do not support the needs in Study A-E (Table 2), like the observation that the solutions used for resource management supported the needs for the police (cell (a,5)). This may be explained in a similar way as the cases where the colours found in Study F are lighter than in Study A-E, i.e. as variations based on characteristics of the operation. This explanation is supported by the findings in the interviews (Table 4) in which the interviewees had experienced other cases where the solutions are not sufficient to cover the needs. An additional explanation is that it may also be the case that the users adapt their work so well to the existing solutions that uncovered needs are not obvious from the observations. If this was the case, it should be revealed in the interviews (Table 4), which it is not. On the other hand, the adaptation to existing solutions may be so strong that the interviewees did not think about it. A third and related explanation is that there are regional differences between how the division of work is divided between the alarm central and the local leaders. This explains why needs, e.g. connected to logging, observed in Study A-E was not confirmed by neither the observations nor the interviews.

If the differences may be explained by characteristics of the operation and/or regional differences, this contradict the finding from Study A-E that support tools should scale to operations of different size and complexity. On the other hand, this need not be problematic as long as a possible support tool does not provide worse support than the solutions used by the agencies today.

The most surprising finding during the observations and interviews was the strong role of the industrial defence. This was not anticipated, and thus we had not planned to do detailed observations/shadowing of or interview the personnel working there. The findings indicate a need for sharing information and support tools that is more difficult to realize organizationally than between governmental agencies.

Summary of findings from all studies

Table 2 shows that for a number of the categories of functionality, we had not found concrete needs for the given category in some of the actors in Study A-E. Our assumption is that this may just as well be an indication of limitations in our findings rather than an indication that the given actors do not have needs for the given functionality. With this in mind, it is interesting to observe that for the police, fire and ambulance services, five of the nine cases where we had not observed concrete needs by these three agencies in the previous studies, we did indeed find a need in the validation activity. To pinpoint this, we present Table 5, which merges Table 2, 3 and 4, i.e. gives the sum of our detailed findings in Study A-F.

	a. Pol.	*b. Fire*	*c. Amb.*	*d. Red Cross*
1. Operat. pict.	*		*	*
2. Incident det.	*	*	*	*
3. Logging			*	
4. Inf. services	*		*	
5. Res. manag.	*			*
6. Actions & pl.				*
7. Transm.		*	*	
8. Monitoring		*	*	
9. Autom. reas.	*	*		*
10. Comm. m.	*		*	
11. Sp. int. m.		*	*	

Table 5. Summary of needs from Study A-F.

The reduction in number of empty cells, as well as the overall picture showing that there are quite few empty cells in Table 5, may be interpreted as a clear indication that the identified categories are general and useful.

RELATED WORK

Martı et al (2009) report the successful implementation of mobile, electronic tags used in the triage process of an emergency response. By this they address our monitoring category explicitly for ambulance services, but their system also partly covers our incident details and resource management categories. Chittaro et al (2007) present a case study developing a mobile application that replaces ambulance run paper sheets, thus addressing our logging category for ambulance services. Büscher and Mogensen (2007) use ethnographical studies and participatory design to develop a prototype of a common operational picture shared by multiple agencies, which is quite similar to our operation picture category. Jiang et al (2004a) address monitoring of fire fighters, thus covering our monitoring category. In their proof of concept prototype, they also apply some functionality covered by our automatic reasoning category. Although focusing on methodology, Humayoun et al (2009) apply their method on a case study focusing on task management, i.e. functionality covered by our actions and plans category. Their case study also includes concrete design of a mobile support system. These are a few examples of research papers focusing on one or a small number of our categories of functionality, often focusing on a single agency and a concrete user interface solution rather than the underlying functionality that this user interface exemplifies.

Jiang et al (2004b) address functionality covered by a number of our categories (like operational picture, incident details and resource management), but focus mainly on development of prototypes enhancing existing solutions for fire fighters, not on identifying categories of functionality. Although they address only fire fighters in their empirical studies and suggested solutions, they argue that similarities between agencies (like common procedures and training) make their results applicable also for other agencies. Kristensen et al (2006) and Kyng et al (2006) also address functionality covered by a number of our categories (like operational picture, monitoring, incident details and resource management), and they also address categories of functionality, but the categories are mainly examples, and cross-agency needs for categories of functionality are not addressed systematically.

Most of the research just presented use empirical methods like field studies, interviews, case studies and participatory design, but do not applied it to generalize as broadly as we attempt. In the cases where more than one agency is addressed, the focus is on the functions themselves rather than the needs for the functions in each agency.

Turoff et al (2004) apply a broad perspective on information systems support for emergency response, outlining among other central information requirements. Their focus is on design principles for such information systems, emphasizing the need for a single, dynamic and integrated system. Hill (2010) presents a HCI development method supporting the development of such an integrated system, while the development method presented by Humayoun et al (2009) addresses more narrow functionality. Streefkerk et al (2006) address both design principles and methods for designing user interfaces supporting emergency response. They focus on adapting solutions to the user's context, as well as the special needs when users are solving attention requiring tasks, but do not address concrete user interface functionality. Also Mazzucchelli and Pace (2004) address adaptive behaviour in emergency response user interfaces, but the amount of work in this field is limited, as is work on applying composition to make emergency response user interfaces more flexible.

CONCLUSIONS AND FUTURE RESEARCH

In this paper we have identified 11 categories of functionality supporting shared needs between different emergency response actors. We have denoted the categories Operational picture, Incident details, Logging, Information services, Resource management, Actions and plans, Transmission, Monitoring, Automatic reasoning, Communication management and Special interaction mechanisms. The work is based on a number of empirical studies involving the police, ambulance and fire services, as well as non-governmental voluntary organizations, and has revealed a large degree of overlap with regards to the needs for (mobile) ICT support when conducting emergency response tasks on the tactical level.

To validate the findings and our conclusions, we have conducted observations and interviews in a training exercise involving the police, ambulance and fire services, predicting that the exercise would not reveal major additional categories of functionality. The validation did not reveal any such additional categories of functionality, but it complemented our initial findings, by concluding needs for some categories of functionality by some of the actors in which such needs had not been observed or expressed in the our earlier empirical studies. Thus, the validation supports our hypothesis that the needs for common functionality in medium size operations within the emergency response field in Norway are covered by the sum of functionality of the 11 categories.

The overlapping and shared needs for user interface functionality across actors, as well as types of operations indicate that providing this functionality through some sort of common or generic mechanism is useful. From an economical point of view, developing identical or very similar functionality for different actors, or maybe even a set of overlapping solution for a given actor to support different types of operations, is definitely a waste of development resources.

On the other hand, the variations that occur between actors, between types of operations, and even between different operations of the same type (e.g. caused by differences in size and/or complexity), indicate that having common mechanisms will not solve the specific needs in each actor, operation type or actual operation. Developing this argument, one may say that a solution that is supposed to fit everyone very easily turns out to fit no one. Furthermore, solutions for attention requiring tasks need to be optimized to the tasks they should support in order to be useful. Despite similarities, it is not likely that the tasks are identical, neither across actors nor across different types of operations in the same actor, and probably even not across different occurrence of the same type of operation. This may be used as an argument against having common mechanisms, but may just as well be used to argue that supporting all variants of such tasks is not feasible from a development point of view.

The solution to this seemingly paradoxical situation is to combine generic functionality with functionality for tailoring. This can be achieved through having a set of user interface mechanisms that each one has some shared core functionality enhanced with flexible means for specializing the mechanisms to the specific needs of each actor, type of operation and characteristics of each operation. This will ease development of solutions that are flexible with regards to type of operation, special needs for the given operation, available and needed information sources, applications and services, available and needed sensors, available infrastructure, type of equipment to be used, work situation of the user, and modalities to exploit.

In addition to ruling out the option of developing optimal solutions for all combination of needs as being utterly expensive, considering the needs for flexibility also indicate that it is very challenging to specify an optimal end user solution in advance. Thus, the common or generic user interface mechanisms should also make it easy to compose an end user solution, partly at design time and partly at run time. Our future research will focus on handling user interface development for applications supporting emergency response, taking the requirements for flexibility into account through applying a model-based approach (Nilsson et al, 2006) to facilitate easy composition of support tools.

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