Cogn Tech Work (2012) 14:169–182
DOI 10.1007/s10111-011-0199-y

ORIGINAL ARTICLE

Temporal aspects in crisis management and its implications on interface design for situation awareness

Anna Gryszkiewicz · Fang Chen

Received: 30 May 2011 / Accepted: 27 September 2011 / Published online: 11 October 2011

Abstract Temporality should be considered in the design of information technology support for crisis management (CM), both because crises are dynamic events and because time is a part of situation awareness (SA). This study has used group interviews to explore how different temporal aspects of CM can be considered in CM design and how they can influence crisis managers SA. A prototype and a scenario were used as mediating materials. The result consists of two parts. The first part is comprised of the participants' reflections on how timelines can be used to display information in CM information systems. According to the participants, timelines should present: deadlines, information sent to the public, incoming and outgoing information, an overview of where the current activities belong in the CM process and what has been going on since the last shift during shift changes. Timelines should not only display the listed information, but also provide functionality for adjusting the timescale so that information can be presented in alternative temporal perspectives. The second part of the result contains several obstacles that might influence the crisis managers' ability to obtain SA. Obstacles elicited from the group discussions are: information overflow, fast changes of SA due to incoming information, difficulties to share SA with actors outside the CM centre, forgetting things that need attention and that SA depends on the quality of incoming information. The two parts of the result have been compiled into six design principles for how temporality can be considered in CM systems in order to support SA.

A. Gryszkiewicz (✉) · F. Chen
Department of Applied Information Technology,
Chalmers University of Technology, Gothenburg, Sweden
e-mail: anna.gryszkiewicz@chalmers.se
URL: http://crisisresponselab.blogspot.com/

Keywords Temporality · Situation awareness · Crisis management · Disaster management

1 Introduction

There are many challenges in the design of information technology for crisis management (CM), including how to create an interface that provides an efficient overview of the crisis situation and other information needed by the crisis managers. In this work, we focus on information technology used by local and regional government when coordinating response activities during a crisis, that is, during an extraordinary event as defined in Swedish crisis preparedness law (Justitiedepartementet 2006). Among the difficulties in presenting an overview of a crisis is the fact that crises are dynamic events that change over time. Response activities with different time frames can go on concurrently, and the continuous information flow into the CM centre can be difficult to take in, as observed by Militello in his study of county level CM exercises (Militello et al. 2007). Because of this, we have chosen to investigate time and temporality with the help of group interviews to explore how time and temporality can be presented in information systems for CM. Additional reasons for focusing on this specific topic are: that human cognition has difficulties in processing temporal relationships (Dörner 1997) and consequently might benefit from support in this area, and because time is an important dimension of situation awareness (SA) (Endsley et al. 2003, Sect. 2.2).

Two important sets of design principles exist today that address different aspects of the design of information technology for CM: the general design principles for emergency response systems defined in (Turoff et al. 2004b) and the design principles for situation awareness in

(Endsley et al. 2003). Temporality is, however, only addressed very briefly in the principles. We therefore see our work as a complement to the existing design principles and that it can provide additional recommendations for how temporality can be addressed in the design of information technology support for CM.

The paper is structured in the following way: The related work section provides an introduction to a number of studies on temporality and SA. The method section explains the choice of group interviews as method for the study and describes the set-up for the study. The outcome of the interviews is presented in the results section. The discussion section further explores the result from a temporal perspective and describes implications for design. The outcome of the study is in this section summarised in six design principles. The final section, conclusion and future work, sums up the result and discussion and suggests how the design principles can be further tested and used.

2 Related work

The related work is divided into two sub-sections. The first contains works connected to temporality, including works on: temporal relationships from a cognitive perspective, visualisation of temporality and representation of temporality from a technical perspective. The second sub-section presents a brief introduction to SA.

2.1 Temporality

Temporality needs to be considered in design, since human cognition has limitations when it comes to appraising relationships in time. The problems with processing temporal relationships are discussed by Dörmer (1997), who presents various illustrations of limitations concerning, for example, assessing processes that grow exponentially, extrapolating the moment when trying to make predictions about the future and, in particular, guessing at missing pieces of information. One point Dörner makes is that when we observe spatial relationships, the full picture can be available to us at once, and we have many opportunities to take another look at the parts of the picture we need to investigate further, but when we try to assess temporal configurations, we have the challenge to do it as they unfold, or afterwards in retrospect.

Cornélis discusses how temporal visualisation can contribute to a better understanding of disasters, in the context of geographic information systems for disaster management:

> Just like referencing phenomenas in space favors a better understanding, their referencing in time also reveals part of the picture. Time is often represented in linear or cyclical ways. These representations allow the visualization of the temporal relations events or their different phases have with one another (simultaneity, succession, recurrence, frequency, length, time shifts, …). (Cornélis 2005).

Temporal relations could in CM mean the relationship between the time for an earthquake and its aftershock, the duration of a storm, the temporal coordination of response activities or any other connection in time between events or activities associated with the crisis.

Temporal visualisation can also be addressed more directly as in (André et al. 2007; Li and Kraak 2008; Luz et al. 2009) who all deal with temporality in three different ways. Continium is a timeline visualisation tool proposed by André. It can be used to represent large amounts of hierarchically structured temporal data and has features that help keeping the presentation clear when zooming in or out. The user can also select which dimensions should be shown. Li, on the other hand, has combined time-wheel presentation and timeline presentation to create time-waves. The time-waves are mainly intended for exploring spatio-temporal data and can be connected to location space and attribute space to offer more query possibilities. Finally, we have Chronos by Luz, which is a temporal mosaic with similarities to gant-diagrams and is used for project planning. In the temporal mosaic, space is allocated proportionally to the number of allocated tasks. Based on the descriptions in the above works, several observations can be made concerning the usefulness of the visualisations for a CM context. Continium appears to be able to handle large amounts of data, but requires the information to have clear hierarchies, while information related to crises can be unstructured. Continium is also not directly designed for handling dynamic real-time information, as might be needed during a crisis, but instead is more focused on visualising historical data. Time-waves can visualise certain aspects of a crisis, such as in Li's example of a time-wave for earthquakes, but is limited (in the same way as regular timelines are) when it comes to visualising large amounts of data that are close in time. Chronos is designed for project visualisations and is not meant to summarise single events or generic information that is not connected to task planning.

Temporal relations can be addressed at a technical level in system design as done by Franke (Franke and Charoy 2010; Franke et al. 2010, 2011) who has developed a generic model for the coordination of activities with temporal dependencies and evaluated the model together with end-users within the emergency management domain. The model is based on "temporal coordination" (Bardram 2009), which is a concept based on activity theory within

the computer-supported collaborative work (CSCW) field. The issue that Franke is addressing is not only a technical one, but arises in any information sharing between actors in CM. Conflicts can arise when different actors have a different understanding of the duration of activities or how events are casually related to each other. Franke uses collaboration between the fire brigade, the police and the military during a flood as an example (Franke et al. 2011). Temporal relations become important in this case, because the fire fighters depend on the military to bring sand bags in order to be able to build a dam protecting the residential area. The police's activities depend on the other actors' activities because they might have to evacuate the residential area. Franke is here addressing temporal relationships from a technical perspective in order to make them more visible to the user, so that conflicts can be avoided or quickly resolved.

Allen illustrates from a technical point of view some of the reasons for why it is challenging to represent temporal information (Allen 1991). He summarises several different ways to represent time (including: date-based representation, representation of fully ordered events and other logical representations) that can be used in order to make the temporal information accessible to for processing in information systems. Among the problems that arise are, for example, missing information about the specific time for when an event occurred or missing information about the duration of events or activities. Furthermore, persistence assumptions arise when people assume that something has not changed since the last time they obtained information about the status of an event or activity.

2.2 Situation Awareness

SA can be described as an individual's understanding of a situation and how the situation is related to goals and tasks. One definition of SA is given by Endsley: "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the future." (Endsley et al. 2003) Based on this definition, SA is divided into three levels: (1) perception of elements in the environment that are important for current goals and tasks, (2) comprehension of their meaning for the goals and tasks and (3) projection of what will happen to the elements in the future and how the situation will develop. SA is not only an individual's understanding of a situation, but can also be shared or distributed among different team members or organisations (Gutwin and Greenberg 2004; Salmon et al. 2009; Stanton et al. 2006; Endsley et al. 2003, chapter 11, pp 193–219).

Time is according to Endsley an important part of SA (Endsley et al. 2003, Sect. 2.2). She states that operators in many domains are interested not only in spatial aspects of the world, but also want to know when an observed element might influence their tasks or goals. Since crisis situations are dynamic and changing, the individual's SA also has to constantly change to stay up-to-date. An example of the difficulties with staying up-to-date is that it might not be known beforehand which information sources will be available during a crisis event. In some cases, there might be completely new information systems or information sources emerging. Two examples of emerging information sources are: when a new information system was developed to support the large-scale contact tracing and data management during the SARS outbreak in Singapore 2003, and when the Singapore Regional Coordination Center (SRCC) developed a web-based Crisis Case Management System (CCMS) for monitoring the availability and demand of aid supplies and assessing how these supplies could be distributed during the Asian tsunami disaster in 2004 (Leidner et al. 2009).

However, it is not uncomplicated to measure and analyse aspects related to SA in a complex CM context by traditional SA design and evaluation methods (Harrald and Jefferson 2007; Salmon et al. 2006). Some of the problems that can be encountered when trying to consider SA in CM system design are: (1) difficulties in ensuring or even knowing data quality, (2) the fact that the actors' different backgrounds cause them to interpret information differently and (3) that the same information is interpreted differently because different actors will have diverse requirements and needs for future action. The main idea from Harrald and Jefferson's discussion about designing for CM is that it is insufficient, and might even be impossible, to gather information requirements in the same way as done in less complex operator environments. Salmon, on the other hand, has evaluated different SA measurement techniques' suitability for a command, control, communication, computers and intelligence (C4i) context (Salmon et al. 2006). Salmon's evaluation is relevant for CM since C4i includes emergency services such as police and fire brigade. His conclusion is that none of the 17 tested SA measurement techniques would be sufficient for a C4i context and also suggests that further research needs to be done in order to investigate whether it is possible to combine several of the existing techniques into a measurement tool that can give a more complete assessment.

3 Method

The conclusion from the previous section is that temporality in the design of CM systems needs to be further explored. In this study, we have chosen to do this through group interviews. This section is structured as follows:

Table 1 Background information on the participants in the groups

	Group 1			Group 2		Group 3	
Group type	County council			Municipality		Municipality	
Participant	A	B	C	A	B	A	B
Title	Risk analyst TiB[a]	Investigator	Security adviser	Security coordinator	Information coordinator	Crime and safety officer	Administrative manager
Years of experience	4	3 (10)[b]	5	10	19	5	12
Age[c]	30–40	40–50	30–40	50–60	50–60	40–50	50–60
Gender	Male	Female	Male	Male	Female	Female	Male

[a] Officer on duty

[b] 3 years at county council and 10 years at university teaching and doing research

[c] Selection from 10-year spans in the background questionnaire

First, we describe the data collection and discuss the choice of group interviews as method. The following sub-sections present an overview of the participants in the study, provide more details on the mediating material (a prototype and a scenario) used in the interviews, describe the procedure for how the interviews were conducted and finally explain how the data was analysed.

3.1 Data collection

The data collection method in this study was group interviews. Three interviews were conducted with participants from three different authorities, one county council and two municipalities. The reason to do three separate interviews was to ensure that the result found in one of the group interviews would not be unique for the specific organisation. This leads to triangulation, since the set-up allows us to identify potentially conflicting statements between the groups, and more confidence can be put into that the result can be applicable to CM at local and regional level overall. Advantages of group interviews are that they may reveal dynamics through interaction and issues not apparent in individual interaction (Gillham 2005). Additionally, according to Gillham, they can provide an early indication of a range of views. The choice of group interviews instead of individual interviews allowed us to talk to people with different CM roles at the same time. Talking to several interviewees at the same time can provide a more nuanced picture of the CM context and reveal, for example, variations in perspective and attitude between the interviewees as discussed by Frey and Fontana (Frey and Fontana 1991).

The group dynamics can make group interviews more difficult to manage, as discussed by both Frey and Fontana, and Gillham. (Frey and Fontana 1991; Gillham 2005) Preventive measures were therefore: running a pilot study before the real sessions, achieving triangulation by having three groups and also by approaching the topic in three different ways in each interview, and finally using mediating materials—the prototype and the scenario—in order to help focusing the discussions and to ensure that the result would contain sufficient detail. Since the outcome from this kind of group interviews is open ended, we also used the analysis process as described in the Analysis subsection to process the data in a structured way.

At the beginning of the study the aim was to learn more about how crisis managers work when following a crisis event and what support may help them to understand the crisis situation. To increase the validity of the result, this topic was addressed in three different ways in each group interview. The first part of the interviews was a general discussion about how the participants work and which information sources they use when responding to a crisis, the second part of the interview was based on discussing a prototype and the third part was based on discussing a scenario.

3.2 Participants

The study consisted of three group sessions with participants as summarised in Table 1.

Crisis managers in several municipalities and a county council were contacted and asked to help in arranging a group interview by suggesting colleagues as participants. The crisis managers were either known to us from previous studies or worked as security coordinators (or corresponding function) in the authorities.

In the invitations, we specified that we wanted participants that had different roles in the CM work (this could mean being officer on duty, security coordinator, information officer and so on). Further, the participants needed to have at least some experience from participating in municipal/county CM or have training for such work. This in order to be users, or potential users, of the kind of CM information systems we are seeking to improve. The contact person's suggestion for participants was discussed with us and approved before a final time for the group session

Table 2 The features of the prototype

Grouping information by event or project	Timeline and checklists
The information is grouped in tabs based on project or crisis event, in accordance with design principle no. 1—organising information around goals—and design principle no. 4—supporting global SA—(Endsley et al. 2003). This arrangement of information can support global SA because the crisis manager can get an overview of a project by looking just in one place, and it organises information around goals by collecting information based on event or project	Timelines and checklists help to provide a global overview in accordance with SA principle no. 4. Timelines can give the crisis manager an overview of events and actions so that the crisis manager does not lose the overall perspective of what has been going on during the crisis even if he at the moment is working on a specific task. The timeline is interactive, so that the user can select an item for more details, for example, to see the meeting notes connected to a CM meeting. The checklists can support the crisis manager in keeping track of important tasks, so that the risk for attentional tunnelling when focusing on a specific problem is reduced
Overview tab	**Building common picture**
The overview tab presents an overview of the geographic area that the crisis manager is monitoring. This tab contains information that might not be connected to a specific crisis event or project, but that can help the crisis manager to monitor slowly developing events that can become a problem. Information might include weather forecasts, rescue service activity, traffic monitoring, and so on. This tab supports design principle 4, and also principle 6–making critical cues for schema activation salient	The prototype shows a system with multiple users. Different crisis managers can contribute with information to the system or get an overview of a crisis or project by using the system. This means that all users can contribute to a common picture that supports team operations: SA design principle 45. The users should be able to adjust what is shown depending on their needs, in for example timeline and checklists, which is important for design principle 47–providing flexibility to support shared SA across functions

was scheduled. All participants came from the respective authority.

Both county councils and municipalities were included in the study, which means that the study covers local and regional perspectives, but not national ones. There are differences between authorities and caution should be taken to generalise result to most Swedish authorities. As participant C in the county council group pointed out during the discussions, the county council has slightly different working conditions since it operates in a big city area, where the rescue service has a large emergency management centre that is capable of managing parts of the coordination work that otherwise would have fallen on the county council. By operating in a coast area, the county council can also collaborate with the coast guard or sear rescue service, which might not be the case in other counties. Nevertheless, the regulations and CM system are the same for all local and regional authorities in Sweden. This means that the conditions for CM work in general are comparable between the authorities participating in the study and other municipalities and county councils. Furthermore, all participants in the study were active in various collaboration networks, training and exercises, with actors outside their own specific authority or area. The systems and tools that are used to support CM work might vary from organisation to organisation, but two commonly used systems by municipalities and county councils are Web-based Information System (WIS) (MSB 2009) and Samverkanswebben (SOS Alarm Sverige AB, 2010). WIS is used for sharing information—for example, operational pictures—between local, regional and national authorities and other organisations that take part in CM work. Samverkanswebben collects information from SOS Alarm and numerous other sources to provide regional and local crisis managers with a map-based overview of accidents, fires, police activities, the traffic situation, disturbances in the electricity supply, weather alerts and other emergency- or crisis-related information. The fact that these systems are commonly used further supports the assumption that there are similarities in the CM work between authorities.

3.3 Prototype design

The following section describes the prototype used in the second part of the discussions. First, the background of the prototype is described, then an overview of the interface is presented and, finally, some methodological concerns are discussed.

Previous studies (Gryszkiewicz and Chen 2010) have provided some general insight into Swedish CM, especially at a municipal and county council level. Several different factors seemed to be important for the crisis manager's understanding of a crisis, for example: the need to know about not only the event itself, but also about the status of the various activities started by the CM group or other actors in response to the crisis event, the dependency on expert interpretation or explanation of information, the use (and non use) of CM centres and the different roles crisis managers can have in the CM. It was this input in combination with several of Endsley's SA principles (see Table 2) that was the foundation for the prototype. The prototype should therefore be considered as a quick sketch

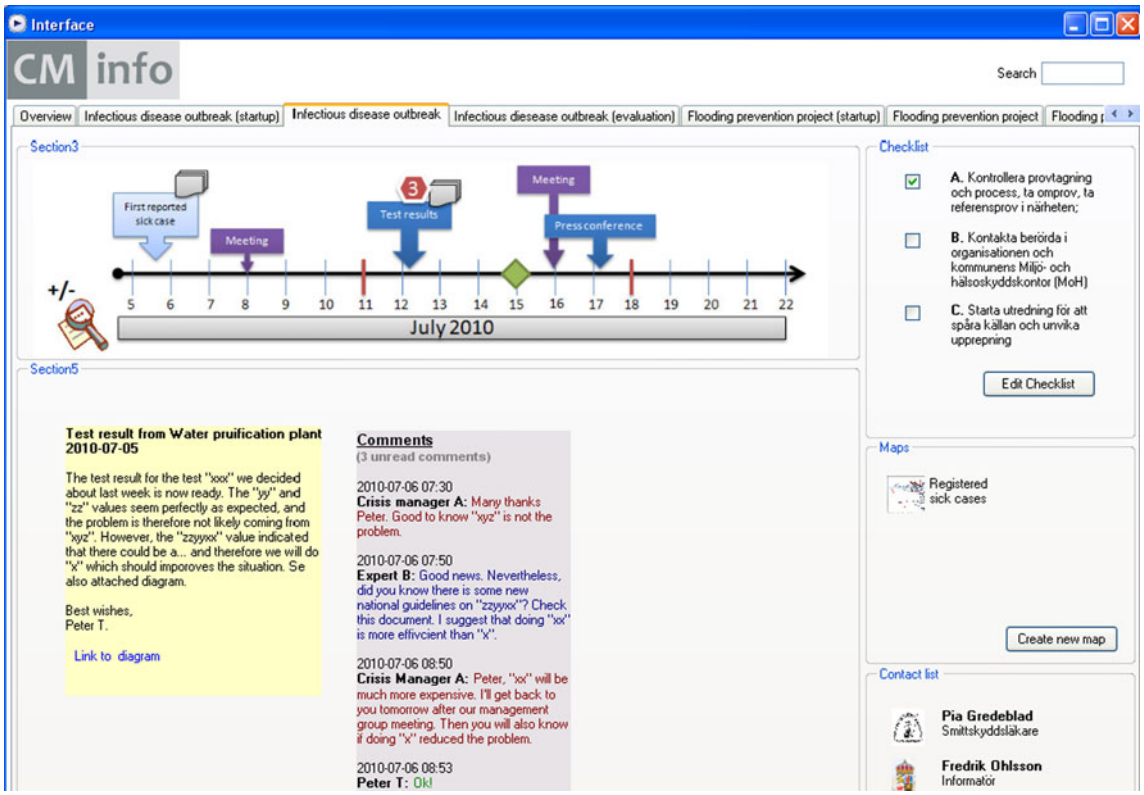

Fig. 1 Screenshot from the prototype

illustrating diverse ideas for features that might contribute to improved SA. The aim of the second part of the interviews was to, for the first time, obtain end-user feedback on which of these ideas according to them should be explored further.

The prototype represents a web-based application, and the interface is illustrated in Fig. 1. It is web-based in order to make information accessible to municipal and county council CM personnel, as well as to CM actors in other locations. The interface consists of different tabs for different crisis events. It is possible to create tabs not only for specific crisis events, but also for other kinds of projects that affect crisis preparedness, like projects for planning new infrastructure or flooding prevention. The first tab to the left is an overview tab that shows events in the geographic area that the crisis manager needs to monitor. The overview tab can include, for instance, weather alerts, traffic information and emergency events. The user can open or close tabs, so that projects that are relevant to current work tasks are available.

Each tab in the prototype is comprised of several different areas. The largest area, at the bottom to the left in Fig. 1, is the main work area where the user sees the information they are currently working with. To help the user keep an overview of the crisis and CM, there is also a timeline and a checklist. The timeline and checklist make it possible for the user to monitor important events even when working on a specific task and can help the user to stay aware of how the current tasks relate to other activities. The timeline is intended to provide overview, and the objective is that the timeline not only presents events and their temporal qualities (time when they occur, their duration, and so on) but also enables quick access to information by providing links to related meeting minutes, status reports or other documents directly from the timeline. In order to support the crisis manager in navigating through the information available during a crisis, the timeline needs functionality for filtering information, zooming and linking to documents and other information sources. The purpose of the checklist is to present activities and deadlines, to help the crisis manager to keep track of important tasks. A tab can also include other functionality, such as contact lists, search features or connection to GIS systems, to help the crisis manger get access to further information when needed.

In order for the system to provide a good overview of CM-related information, it needs to be connected to various information sources. If a crisis preparedness plan is updated, it should appear on the timeline and become accessible through other search features in the system. It might also be interesting to connect the system to geographic information systems (GIS) or communication tools, such as e-mail,

Skype and mobile phones, which could allow the crisis manager to send out a notification about updates in the system through e-mail or text messages. Such a connection could additionally allow the crisis manager to forward a certain piece of information to colleagues, or could be used for automatic logging of events, as when a Skype meeting automatically is recorded and stored together with meeting minutes and made decisions. Information integration between different actors and information systems is a large topic, and other studies and projects have been looking at this issue more in detail. Two of these projects are Service-Oriented Architectures Supporting Networks of Public Security Sector (SoKNOS) (SoKNOS-konsortsioum 2009) and ISyCri project (Truptil et al. 2010).

Another aspect of providing information through a computer interface is that it might be more difficult for the user to ask for clarification or discuss the meaning of the presented data, compared to when information is shared in person. Design principle 5 (Turoff et al. 2004b) states that it is important to provide links to the original information source for information in emergency response systems. According to Turoff, linking to the human source might be necessary in many cases, for example, to allow the crisis manager to ask for updates related to resource allocation. To support the user in asking for updates or clarification of information, the interface can, for example, provide linking to the original information source, linking to further information, commenting opportunities (as illustrated in the work area in Fig. 1) and contact lists.

The prototype was created in Serena Prototype Composer and therefore has a high-fidelity look and feel, but it should be considered as a sketch presenting various ideas for further discussion. As discussed by (Rettig 1994), it is a common problem that test persons focus too much on appearance when high-fidelity prototypes are used. In practice, this was not a major obstacle, since the participants seemed to understand the purpose of the prototype after it was explained. The prototype design had most impact on the second part of the discussions and was not directly used in the first or third parts.

3.4 Scenario

The scenario used in the third part of the group sessions was about an outbreak of waterborne infection. The scenario was based on a case in Lilla Edet in 2008 (Gryszkiewicz and Chen 2010) in order to use a realistic event as the basis for the scenario. It has been estimated (based on questionnaires sent out after the outbreak) that the outbreak of Calici virus in Lilla Edet caused 2400 sick cases, affecting one-fifth of the population in the municipality (Ekvall 2010). The groups were given a scenario where a waterborne infection had affected their municipality or county and lead to several hundred sick cases. The source of infection was not known at the beginning of the event, but all signs would be indicating that the infection was waterborne. The specific sequence of events or response activities was not specified beforehand, because the objective was to allow the participants to describe how an outbreak of waterborne infection would be handled by their specific authority. This includes which response actions would be taken by the CM group and what other actors (both organisations and individuals) the participants would be exchanging information with. The scenario was chosen because providing a drinking water supply is a central societal function and especially important for municipal CM, since municipalities are responsible for monitoring the quality of the water (National Food Administration 2010). To sum up, the participants have not been directly involved in a real event as in the scenario, but are likely to be familiar with routines for how their organisation would respond, since possible risks to the drinking water supply is a common concern from a local or regional CM perspective. Municipalities and county councils do, however, have slightly different perspectives on water borne infections. Municipalities are more directly involved in the response work, while county councils have a more high-level role. County councils can, for example, help with expertise or coordinating contacts to national authorities and organisations such as the Swedish National Food Administration or the National Water Catastrophe Group (which is a support group of experts who can provide advice on crises that affect the water supply).

3.5 Procedure

Each group session was 2 h long and was voice recorded. The group discussions were held at the participants' facilities, which allowed the first author to see the work context in which the participants usually performed CM. This included being showed around in the regular office environment as well as seeing the CM centres, in those cases where there were specific premises prepared for this purpose. For more details on municipal and county council CM work environment in Sweden, see (Gryszkiewicz and Chen 2010).

The group sessions started with a brief introduction to the background of the study and a presentation of the agenda for the meeting. A short questionnaire was handed out to collect background data such as previous experience, age, gender, name, current job title and work tasks. Before the beginning of the discussion itself, the participants introduced themselves and their area of responsibility.

The first part of the discussions was focused on what kind of CM-related work tasks and activities the participants are involved in—both when responding to a crisis

and when involved in planning, prevention and evaluation activities—and more specifically what information sources and systems they use as a help in obtaining an overview of an event. After this general opening, a prototype was presented to direct the discussion more explicitly to how interfaces can support overview and understanding of the crisis (and thus SA). The discussion went from generic to detailed aspects of the design. Issues such as how to group or navigate through information were brought up in the beginning, and the discussion continued with details about timeline, checklist and other features. The final part of the discussion was about the scenario. The participants created a timeline using post-it notes on a large sheet of paper to represent a possible sequence of events during a crisis as in the scenario. The session ended with a summary and time for additional comments from the participants. All three sessions followed the same outline, and the time was divided as equally as possible between the three discussion topics, but naturally with minor variations depending on what the participants chose to comment on. The exception was the first session in which there was not enough time to do the final scenario part. After the first session, it was clear that there would not be enough time to discuss two scenarios as originally planned, and the aim for the remaining groups was to have one discussion based on the scenario described in the Scenario design sub-section.

3.6 Analysis

The collected data from the group discussions consisted of voice recordings, a few photographs, answers to the background questionnaire and a timeline of the scenario on a large sheet of paper. The first step in the thematic analysis consisted of collecting the different data into one document for each interview group. The voice recording was transcribed and then coded by the addition of labels describing the topic of a comment or the topic of a group of comments. The three documents will hereafter be called the data documents.

Based on the data documents, we searched for topics that seemed interesting in some way, for example, because a topic had attracted a lot of discussion, because some comment seemed to be potentially important for how CM information systems should be designed or because there seemed to be differences in opinion between groups or participants. This is an in-depth data exploration of the empirical material that is recommended for the beginning of case study analysis by Yin (2009), but which also was suitable in this study as a way to become familiar with the qualitative data. Based on the content in the three data documents, we decided to continue the analysis by doing one analysis for the comments related to the prototype (coming from the second part of the group interview) and one analysis for all other comments (coming from the first and third part of the group interview).

Comments regarding the prototype were collected from the three data documents into one table. These comments were subsequently grouped based on what interface feature they address. In this table, we could identify many comments related to the timeline and that these comments seemed to address critical aspects interface design. Therefore, this part of the table was selected for further analysis.

As mentioned earlier, the first and second parts of the group interviews were analysed together. Due to our focus of identifying aspects that could influence SA, we looked at the data documents and selected all comments addressing the understanding of a crisis. These comments were collected into a table which was divided into one section for each SA level. Comments that could relate to several SA levels were put in all sections of the table they applied to. An inspection of the comments in the table resulted in the identification of various obstacles that might limit the crisis manager or CM group in obtaining SA.

To summarise, after this analysis, we had two tables with results. One table contains comments about the timeline in the prototype, and one table contains elements that might influence the crisis managers understanding of a crisis situation. Based on this analysis, design principles have been identified to consider temporality in the design of information technology support for CM.

4 Results

The result consists of two parts. The first part is about the participant's suggestions about potential uses of a timeline, and the second part focuses on how the participants comprehend dynamic events, share information with others and what problems can arise in this context. The first part of the result is based on part 2 of the group interviews, that is, the prototype discussion, while the second part of the result is based on part 1 and 3 of the group interviews.

4.1 Using timelines for diverse objectives

There was a general consensus in all three groups that a timeline is helpful in understanding crisis events. The participants gave examples of what the timeline should be used for, as summarised in Table 3. It was suggested that the timeline could be a support during shift changes since it provides an overview of what has happened since the last working period. This could reduce the time it takes to inform a colleague who is taking over the work tasks and also reduces the risk for later problems if the person leaving a shift has forgotten to share a specific piece of

Table 3 The discussion groups' suggestions for how the timeline could be used

	Timeline usage suggestion	Comment by group
1	Incoming and outgoing information should be presented in the timeline	1
2	The timeline should give an overview of where you are in the CM	1
3	The timeline can be useful during shift changes to provide new personnel an overview of what has been going on since their last working period	2
4	The timeline should be connected to checklists so that it can show deadlines for exercises and when different planning documents need to be updated	2
5	Timeline needs to be adjustable so that different time perspectives can be visualised	3
6	Information sent to the public should be presented in the timeline	3

information that the successor later needs to know about. The participants meant that, by and large, there is a need to know what has been done earlier in the CM. A participant from the county council group explained this by saying:

> You always need to go back later, because if you have made a decision, and taken actions based on that, then we want to know: What did it look like then? What did we know? You notice that you mix up things after a while, and you start to question' why did we do that now?' and the actions do not fit the image you have, but when you go back and check you notice that we actually did not know this or that at the time. (Participant B, group 1)

Participants suggested that the checklists should be included in the timeline. That is, it should be possible to see different deadlines on the timeline, for example, deadlines for exercises or when different planning documents should be updated. This is because it can be difficult to keep track of different deadlines when the crisis manager is involved in different activities and diverse tasks might require immediate attention. Furthermore, the participants in group one wanted to see incoming and outgoing information on the timeline, especially:

> All information that comes to us. All requests, all documents and decisions that leaves us. (Participant C, group 1)

The impression was that this is information they usually need to keep track of or locate at different points in their work, for example, due to media requests or to follow up a request from another actor.

In the discussions, the participants referred to diverse activities of CM, such as, fire prevention work, project work, planning, handling a pandemic or flooding. The participants also gave examples of crisis events that might require different timescales:

> If you have an event that is developing slowly over time, then we might have a CM meeting once a week or twice a week, and if you have a very intense event then you maybe have a meeting in the morning and afternoon every day. (Participant B, group 1)

This implies that a timeline has to be able to support alternative temporal scaling in order to be of use in different CM contexts.

Group three, consisting of municipality personnel, reflected on that they are a local authority and therefore have a good understanding of the local conditions and that this, according to the participants, means that they have a special responsibility for the public. They meant that information spread to the public through, for example, their website and press conferences sometimes influences the CM and therefore should be visible on the timeline. If something is unclear in the published information, the municipal switchboard might, for example, receive a large number of phone calls, and then, the CM group needs to be able to go back and check when and why something was published.

Table 3 summarises the suggestions for how a timeline should be used. The variety of suggestions illustrates that a timeline does not necessarily have only one role, but that different actors might have different objectives and that objectives might change depending on context.

4.2 Comprehending dynamic events and activities

During the discussions, participants from all groups brought up factors relating to their work context that can be an obstacle for understanding a crisis and consequently for obtaining SA. Operational pictures are mentioned as one way to present and share an understanding of what is going on. Participants in group 1 mention operational pictures in the context of WIS, a web-based CM information system for information sharing, which has a specific template for sharing operational pictures, and participants in group 2 considered the creation of a common operational picture to be one of the objectives of their CM meetings. According to the participants in group 2, the CM group can consist of both municipal officers and representatives from other organisations:

> It can be Fortum [an electricity supplier] if there is a power outage, the police, or the rescue service. They send a liaison officer to our group, and then they have

> their own headquarters as well of course, in their own organisation, with whom they stay in touch through phone as long as they are a part of our group. (Participant A, group 2)

Furthermore, an operational picture is compiled by discussion in the CM group:

> When there is a meeting, you go around the table and everyone presents their view of the event. Fortum says: this many properties are affected by power outage, and so on. The rescue service then notes that: this is a problem to us, since we don't have any water in this area because the pumps have stopped working [due to the power outage], and so on. Then, everything is weighted together and a decision is made. (Participant A, Group 2)

According to the participants' descriptions of operational pictures, they would be influenced by the individual crisis manager's ability to bring forward important information about the situation. When creating the operational picture, crisis managers depend on reports from other actors, such as electricity companies, weather services, police or even the public. Another SA obstacle in crisis coordination centres is that information is presented physically on walls, on maps and whiteboards. This means that it is difficult to obtain shared SA with actors that are not present in the room.

Information overflow is also an obstacle for SA, as exemplified by participant C in group 1 when talking about the CM work related to the H1N1-flue in 2010:

> During the pandemic, there were so many documents and information coming in, that finally it became messy to get an overview of everything. (Group 1, participant C)

The different groups also discussed that it is easy to forget activities, questions or things that need to be monitored during CM. For example, when the CM group is focused on an important task, and there are smaller issues that have not yet evolved into a real problem, but need to be monitored so that the CM is ready to handle it when the situation changes.

Prediction of how the crisis will develop is important for level 3 SA and is also one of the more challenging things to support through information technology. The following quote is from the scenario discussion and illustrates how worst-case scenarios are used as an attempt to understand future development:

> Even if we do not know anything about the event, we need to be asking the right questions. The CM group would be looking into for example what if the event becomes worse? What is the worst case scenario? Every manager needs to look into this for their area of responsibility. The chief executive is responsible for directing people to think in a larger perspective. (Group 3, participant B)

Finally, the operational picture can change very fast in CM, which means the SA consequently needs to change to reflect the new situation. One participant described changing operational pictures in the following way:

> When you discuss the issues, then you get a common operational picture at that moment. On the other hand, it can change very quickly, it's enough if you leave the room and someone then gets a phone call from their headquarters and suddenly the operational picture is different. (Participant B, group 2)

The main findings of the SA obstacle part of the result are summarised in Table 4.

5 Discussion

Several important observations have been made in the analysis of the collected data by applying temporality as an analytical lens. Obstacles 1 and 4 Table 4 are both connected to that SA problems arise when several people are involved in the information sharing connected to the crisis and especially when information needs to be shared between geographically distributed actors. The problem is not only the geographic distance itself—since information can easily be transferred by making a phone call or using some other available communication tool—but that different activities are going on asynchronously in the different locations. In participant A group 2's quote in the result section, the rescue service needs to adjust their activities because the electricity company is reporting that there is no power supply in an area. It could just as well be a municipality waiting for a laboratory to evaluate test results after an outbreak of waterborne infection or county council crisis managers coordinating their activities with other actors in the region in preparation for an approaching snow storm. Both events and CM activities have different dependencies based on time, and understanding the

Table 4 Obstacles in CM that can influence SA

Obstacle	Description
1	SA is difficult to share with actors outside the CM centre
2	Information overflow
3	Forgetting things that need attention
4	SA depends on the quality of the operational picture
5	SA changes quickly due to incoming information

dependencies can help the crisis manager to understand the crisis situation. As Dörner points out (Dörner 1997) people have more difficulties comprehending temporal relations compared to spatial. In the timeline discussion, participant B in group 3 pointed out the need to be able to go back and check past information, and this also indicates the wider problem of understanding dynamic situations. Being aware of the temporal relations between events and activities could additionally help the crisis manager to understand what tasks or information they need to pay attention to at a given moment (obstacle number 3, Table 4).

Information overflow (obstacle number 2, Table 4) is another problem related to that multiple CM activities are going on concurrently. A crisis manager might be able to monitor one activity closely, but is not able to monitor a large amount of activities at the same time. Because of this, the crisis manager relies on reports and summaries from liaison officers as mentioned in the result section. The SA problem that arises is that it becomes very difficult for the crisis manager to obtain a completely up-to-date picture of the events. The picture of the current situation, which is presented in meetings or by CM systems, will always be more or less delayed since the reporting itself takes time. A further consequence of this is that the crisis managers SA might quickly change as new information comes in, obstacle number 5 Table 4. New information could here mean a weather prognosis predicting a storm that was not observed in the previous prognosis or when a county council adjusts the CM activities based on new reports from the municipalities in the region. Data overload[1] is a common problem for SA, as pointed out by Endsley, who also makes the noteworthy comment that we sometimes miss that data overload in reality often is a function of the way that data are processed, stored and presented in many systems (Endsley et al. 2003).

5.1 Implications for the design of CM systems

When (re-)designing CM systems, it is important to take into account that crisis events change over time. The design principles presented in this section are intended to supplement other design principles (for example those suggested in (Endsley et al. 2003; Turoff et al. 2004b)) by focusing on temporal aspects of CM systems. The objective of the principles is to be useful when evaluating the interfaces of existing CM systems, but also in other design activities concerning CM systems where it might be beneficial to reflect on temporal aspects of the design. The principles have been created by an analysis of the result of the group interviews from a temporal perspective. This means that the principles primarily, but not exclusively, address design of CM systems used by municipal and county crisis managers when monitoring, for example, crisis response, planning or evaluation activities. In addition to the foundation in the empirical material, the principles are also supported by the connection to the literature on temporality and SA. Because of this, the principles are addressing issues that can be of interest also in other kinds of CM information systems.

The presentation of the principles comprises (1) introduction based on the empirical result, (2) discussion in relation to theory and/or related work and (3) conclusion and summary of what the principle implies for design.

5.1.1 *Principle 1: Make temporal relationships between asynchronous activities salient*

The analysis in the previous section showed how different CM actors concurrently work on different activities. Each actor has a distinct role, with distinct goals and priorities for their activities. Since the different actors, nevertheless, have the common goal to respond to and mitigate the effects of a crisis, they all need information about temporal aspects of the event and of each other's work. CM systems can help the crisis managers to understand the situation by presenting temporal relationships between events and activities. Temporal relationships can be, for example, simultaneity, succession, recurrence, frequency, length, time shifts, as suggested in (Cornélis 2005). However, Franke observes that it is difficult to define dependencies between different actors' activities beforehand. (Franke et al. 2010). Temporal dependencies in CM during an outbreak of waterborne disease could be when municipal crisis managers are waiting for water analysis test results from a laboratory before cancelling water boiling recommendations. Other dependencies might be how events are connected to each other in time, like for instance the time between when a response action is taken until there is a decrease in the number of new sick cases.

5.1.2 *Principle 2: Make information about past crises, and past CM events in ongoing crises, easily accessible*

Keeping information about past events and activities easily available in a CM system aids memory. Since humans have limited memory resources, they are likely to forget important information about a crisis as the CM goes on for days, weeks or even is continuously ongoing like in a project for monitoring climate change. See obstacle 3

[1] "Information overflow" and "data overload" are in this text used to refer to the same issue of information processing. Data are used by Endsley to make a clearer distinction between any information that can be made available to a system operator, and the specific information that actually is useful to the operator in a specific situation.

Table 4. Information about past crises and past events in the ongoing crises can therefore be essential to understand an ongoing crisis. Information about previous flooding can, for example, help in taking appropriate response actions to an ongoing flood, and previous epidemics can help explaining how a disease is spreading.

5.1.3 Principle 3: Add create/last modification time-stamps to information

As discussed in the previous section, presenting up-to-date information is difficult when a situation is constantly changing. A system can guide and support its users by showing create/last modification time of a data set. Such time-stamps can label weather prognosis creation, last test result update or progress report creation. The importance of time-stamps and other labels making information traceable back to its source was discussed by Turoff in his general design principle number 2 for emergency systems (Turoff et al. 2004b). Turoff's design principle 2 points to any marking that makes information traceable to the source, and the specific point we want to add is that create/last update time-stamps especially can help the crisis manager to understand what the situation looks like right now. Without time-stamps, crisis managers will have problems in determining how recent information is and whether it is reliable.

5.1.4 Principle 4: Indicate how events and activities may develop

As illustrated by the quote from group 3 in the result, even when you do not know how an event will develop, it is important to ask questions and discuss possible outcomes in order to get a picture of what might happen. According to Endsley, it is possible to help operators to do projections for operator tasks by using trend displays or by visualising temporal parameter changes (Endsley et al. 2003). Endsley also mentions displays that "allow operators to anticipate possible occurrences" to be helpful for the operators ability to create accurate projections. Projecting future events is a part of level 3 SA. For the design of CM systems, visualising temporal parameters could mean illustrating how a flood would spread as a function of rainfall or presenting how many and what kind of phone calls the switchboard is getting concerning a crisis over time. Furthermore, by presenting worst-case scenarios, showing alternative outcomes, or visualising constraints for how an event can develop, the crisis managers can start discussing and preparing response activities. For example, if a worst-case scenario is presented for a flood, then it can be used as a foundation for discussions regarding potential damage to infrastructure, what resources might be needed, and evacuation plans, even when the actual consequences of the flood are not yet known.

5.1.5 Principle 5: Support alternative temporal scaling

A CM system needs to support work on alternative timescales (point 5, Table 3), which means, for example, presenting information on different timescales depending on the crisis manager's role and tasks. One reason alternative temporal scaling is needed is that crises and CM activities can last for different durations. A chemical industry incident might only be in focus during a few days, while a flooding prevention project might go on for several years. Since the timescale of CM work varies, CM systems need to support shift changes and transferring of tasks between teams and individuals in CM when the duration or timing of activities makes it necessary for more than one individual to be involved in a specific task. This is, for example, discussed in the DERMIS framework design premise number 5, summarised in (Van de Walle and Turoff, 2008) based on (Turoff et al. 2004a, b). Premise number 5 is about the *scope and nature of a crisis* and specifically focuses on that different actors might be active in different phases of a crisis and that tasks might be transferred between different teams or actors. Tasks can also be transferred between individuals when crisis managers work in shifts or need breaks. To summarise, this means both that the system should be able to present information on alternate timescales, but also that it can support, for example, shift changes that occur when different people are responsible for the same activities over time.

5.1.6 Principle 6: Give support for emerging information sources

Municipal and county council crisis managers' understanding of a situation (and consequently their SA) will depend on information coming from other organisations, or systems they are not using daily, as described in the quotes by participant A in group 2 in the result. Furthermore, Leidner provides examples of how new systems are developed on demand during crisis events to solve information gathering needs during crises (Leidner et al. 2009). It is consequently necessary to consider the handling of emerging information sources in the design of CM systems. A CM system needs to be able to collect information from sources that might not have been known beforehand or that might not even have existed before the crisis event. This principle is connected to temporality since information sources can change over time, the information technology support needs to allow for that kind of flexibility.

6 Conclusion and future work

This work has explored temporality in the design of information technology for CM support. From a research perspective, it contributes with a better understanding of how temporality can affect SA in a CM context. It is a challenging task to assess and design for SA in a complex environment such as CM, and we have therefore used group interviews to gain insights on possible obstacles that might hinder crisis managers from obtaining SA. We have specifically addressed how different aspects of CM work might influence both the CM group's and the individual's SA. Obstacles elicited from the interviews are: information overflow, fast changes of SA due to incoming information, difficulties to share SA with actors outside the CM centre, forgetting things that need attention and that SA depends on the quality of incoming information. This work also contributes to practice, through the collected end-user input on the usefulness of timelines as a visualisation tool for crisis-related information. According to the participants, timelines should present: deadlines, information sent to the public, incoming and outgoing information, an overview of where the current activities belong in the CM process and what has been going on since the last shift during shift changes. Timelines should not only display the listed information, but also provide functionality for adjusting the timescale so that information can be presented in different temporal perspectives. The main contribution of this paper is the design principles that are based on all the findings mentioned above.

The suggested design principles need further validation since the empirical material depends on the interviewees' descriptions of CM work. We intend to do this by comparing the findings to the designs of two CM information systems that are in use in Sweden. The evaluation will be done through interviews with crisis managers, since this allows us to study information from real crisis events and to take advantage of the users' knowledge about how and why the system has been used. The result will be used to assess whether the design principles are useful in practical evaluations of CM information system interfaces and to refine them where appropriate. Temporality in CM is a broad topic that can and should be investigated in more ways than has been possible in this work. It would, for example, be interesting to make a more thorough comparison between timelines and other alternatives for visualising temporality to further explore how they can contribute in a CM context.

To conclude, the findings indicate that temporal visualisation in CM support systems can be of help to the user, but further work is required to learn more details about efficient ways to approach this.

References

Allen JF (1991) Time and time again: the many ways to represent time. Int J Intell Syst 6 (4 special issue):341–355

André P, Wilson ML, Russell A, Smith DA, Owens A (2007) Continuum: designing timelines for hierarchies, relationships and scale. In: Proceedings of the 20th annual ACM symposium on user interface software and technology (pp 101–110). ACM. Retrieved from http://portal.acm.org/citation.cfm?id=1294211.1294229

Bardram JE (2009) Temporal coordination on time and coordination of collaborative activities at a surgical department. Comput Support Coop Work 9(2):157–187. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2974339&tool=pmcentrez&rendertype=abstract

Cornélis B (2005) Framing spatial decision-making and disaster management in time. Geo-information for Disaster Management, 281–293. Springer. Retrieved from http://www.springerlink.com/index/t006p6430274096n.pdf

Dörner D (1997) The logic of failure: recognizing and avoiding error in complex situations. Perseus Books, Cambridge

Ekvall A (2010) Outbreak of calici virus in Lilla Edet–course of events and conclusions. vav.griffel.net. Stockholm. Retrieved from http://vav.griffel.net/filer/Rapport_2010-13.pdf

Endsley MR, Bolté B, Jones DG (2003) Designing for situation awareness: an approach to user-centered design. Taylor & Francis, Boca Raton

Franke J, Charoy F (2010) Collaborative coordination of activities with temporal dependencies. Lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics), 6426 LNCS (PART 1) (pp 186–203). Retrieved from http://www.springerlink.com/index/W476140616360V75.pdf

Franke J, Charoy F, Ulmer C (2010) A model for temporal coordination of disaster response activities. In: Proceedings of the 7th international ISCRAM conference (pp. 1–11). Retrieved from http://hal.archives-ouvertes.fr/inria-00505194/

Franke J, Charoy F, Ulmer C (2011) Handling conflicts in autonomous coordination of distributed collaborative activities. In: 2011 IEEE 20th international workshops on enabling technologies: infrastructure for collaborative enterprises, pp 319–326. Ieee. doi:10.1109/WETICE.2011.73

Frey JH, Fontana A (1991) The group interview in social research. Soc Sci J 28(2):175–187. Retrieved from http://www.sciencedirect.com/science/article/pii/036233199190003M

Gillham B (2005) Chapter 9: group interviewing. Research interviewing, the range of techniques. McGraw-Hill Education, Berkshire

Gryszkiewicz A, Chen F (2010) Design requirements for information sharing in a crisis management command center. In: 7th international conference on information systems for crisis response and management. Seattle, 2 May to 5 May

Gutwin C, Greenberg S (2004) The importance of awareness for team cognition in distributed collaboration. Team cognition: Understanding the factors that drive process and performance, 201:1–33. Citeseer. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.17.6293&rep=rep1&type=pdf

Harrald J, Jefferson T (2007) Shared situational awareness in emergency management mitigation and response. System sciences, 2007. HICSS 2007. In: 40th annual Hawaii international conference on (p. 23). IEEE. doi:10.1109/HICSS.2007.481

Leidner DE, Pan G, Pan SL (2009) The role of IT in crisis response: lessons from the SARS and Asian Tsunami disasters. J Strateg Inf Syst 18(2):80–99. doi:10.1016/j.jsis.2009.05.001

Li X, Kraak M-J (2008) The time wave. A new method of visual exploration of geo-data in time–space. Cartogr J 45(3):193–200. doi:10.1179/000870408X311387

Luz S, Masoodian M, McKenzie D, Broeck WV (2009) Chronos: a tool for interactive scheduling and visualisation of task hierarchies. In: 2009 13th international conference information visualisation, pp 241–246. Ieee. doi:10.1109/IV.2009.88

Militello LG, Patterson ES, Bowman L, Wears R (2007) Information flow during crisis management: challenges to coordination in the emergency operations center. Cogn Tech Work 9(1):25-31. Retrieved from http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-33847329577&partnerID=40

MSB (2009) WIS information page. Retrieved April 18, 2011, from http://www.msb.se/sv/Produkter–tjanster/WIS/

National Food Administration (2010) Dricksvatten. *2010-10-27*. Retrieved February 2, 2011, from http://www.slv.se/sv/grupp1/Dricksvatten/

Salmon PM, Stanton NA, Walker GH, Green D (2006) Situation awareness measurement: a review of applicability for C4i environments. Appl Ergon 37(2):225–238. doi:10.1016/j.apergo.2005.02.001

Salmon PM, Stanton NA, Walker GH (2009) Distributed situation awareness: theory, measurement and application to teamwork. Ashgate Publishing. Retrieved from http://books.google.se/books?id=yGa1fvGhNpkC&dq="distributed+situation+awareness"&source=gbs_navlinks_s

SoKNOS-konsortsioum (2009) SoKNOS. Retrieved September 12, 2011, from http://www.soknos.de/

SOS Alarm Sverige AB (2010) Samverkanswebben–beskrivning. *2010-05-12*. Retrieved February 7, 2011, from http://www.sosalarm.se/sv/Nyheter-och-Media/Pressmeddelanden/Arkiv-2009/Samverkanswebb-ger-samlad-lagesbild/

Stanton NA, Stewart R, Harris D, Houghton RJ, Baber C, McMaster R, Salmon PM et al (2006) Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology. Ergonomics 49(12–13):1288–1311. doi:10.1080/00140130600612762

Truptil S, Bénaben F, Pingaud H (2010) A mediation information system to help to coordinate. Ifip International Federation For Information Processing, pp 173–180

Turoff M, Chumer M, Hiltz SR, Klashner R (2004a) Assuring Homeland security: continuous monitoring, control & assuran. J Inf Technol 6(3):1–24

Turoff M, Chumer M, Van de Walle B, Yao X (2004b) The design of a dynamic emergency response management information system (DERMIS). JITTA 5(4):1–36. Hong Kong University Science and Technology. Retrieved from http://web.njit.edu/~turoff/Papers/dermis2004.htm

Van de Walle B, Turoff M (2008) Decision support for emergency situations. Inf Syst e-Bus Manage 6(3):295–316. doi:10.1007/s10257-008-0087-z

Yin RK (2009) Case study research: design and methods, 4th edn. Sage, Los Angeles