THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

Temporality in the Interaction Design of Information Systems for Crisis Management

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Time and Temporality in the Interaction Design of Information Systems for Crisis Management
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Cover:
An early sketch illustrating the thought model presented in this thesis using post-it notes. Photo by Sus Lundgren.

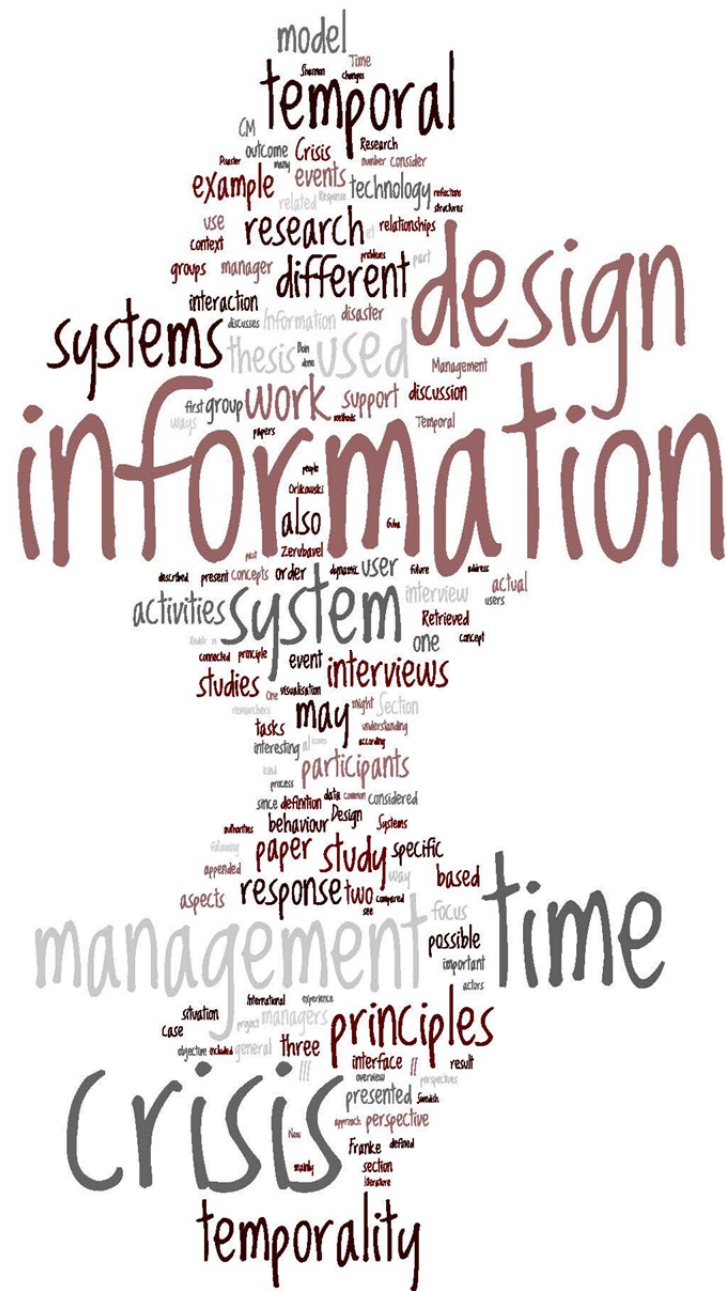# TEMPORALITY IN THE INTERACTION DESIGN OF INFORMATION SYSTEMS FOR CRISIS MANAGEMENT

ABSTRACT

This thesis contributes with two tools that can be used by designers and researchers in exploring how to address time in the design of crisis response and management information systems. By crisis management information system is here meant information systems used by local and regional authorities when responding to events that may disturb important societal functions, such as: floods, storms, terror attacks, and spreading of infectious diseases. Crisis management information systems need to consider temporality - that is, different aspects of time - because crises are dynamic and changing over time. An information system may be intended to support the coordination of crisis response activities, situation awareness, time-critical decision making, or the visualisation of crisis related information. All these elements depend on time. The issue is how to consider these diverse aspects of time when creating an interface for a crisis management information system. This thesis explores time from an interaction design perspective and contributes with the following tools providing support in the design work:

1) ***A set of design principles for temporality.*** The design principles highlight a number of issues of how crisis management information systems support different characteristics of time. The design principles address some aspects of: how temporal information is presented in an information system, and how to consider the temporality of the behaviour of the information system.

2) ***One thought model supporting exploration of temporality in information system design.*** The thought model is a foundation for reflecting on how time may influence the use of an information system and what design issues this may lead to.

The design principles and thought model are based on three studies, which together include participants from local, regional, and national crisis management. The first two studies used individual and group interviews for data collection, and produced a set of tentative design principles for temporality. The third study assessed and improved the design principles based on two national crisis management systems. The thought model is based on a synthesis of the overall outcome from the three studies.

The intended audience for this thesis is any researcher or designer looking for a structured way to approach temporality in the design of crisis management information systems. Both the design principles and the thought model can be used to explore temporality irrespective of whether an objective or subjective perspective is used on time.

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TIME FOR THANKS

LIST OF APPENDED PAPERS

This thesis is a summary of the following three papers.

    I.   Gryszkiewicz, A., & Chen, F. (2010)
        Design requirements for information sharing in a crisis management command center. 7th International Conference on Information Systems for Crisis Response and Management. Seattle, 2 May to 5 May

    II.   Gryszkiewicz, A., & Chen, F. (2011)
        Temporal aspects in crisis management and its implications on interface design for situation awareness, Cognition, Technology & Work - In press, published online

    III.   Gryszkiewicz, A. (2012)
        Evaluating design principles for temporality in information technology for crisis management, International Journal of Information Systems for Crisis Response and Management – Volume 4, Issue 1

Contents

1 PRELUDE[1]

Maria is a security coordinator in the small municipality of Frostby who is coordinating the response to a snow storm hitting the area. Sofia, an interaction designer, is following and documenting Maria's work.

The phone is ringing as Maria sits at her desk in the city hall in Frostby. She is entering a progress report about how Frostby is managing the consequences of the sudden snow storm into Crisis Information Forum (CIF), the national information system used for sharing crisis related information. Maria is new on the job and thinks it is excellent that she can see her predecessors notes, because she has learnt a lot about routines, reports and how crisis are handled in Frostby just by browsing through the past notes. Maria is tired after a long shift, but hurries to answer the call:

- *The municipality of Frostby, Maria speaking.*
- *Hi Maria, Nils Bengtson here, responsible for the elder care services. I'd need your help, please.*
- *Is it about the snow again? Is there a problem?*
- *I'm afraid so. Our personnel has trouble reaching the old people still living at home because of the snow. I'd like to coordinate our visits to the elderly with the snow clearance so we can reach those who need assistance faster. We're especially worried about the Skottbo area, since four people there depend on medication we can't deliver. No use to send a request through CIF…*
- *I know, I know, snow clearance are not monitoring CIF continuously, it's not designed for urgent requests. I have the number to Lars Skog here, try that and let me know if you decide on any plans.*
- *Thanks! I'll let you know in the crisis management meeting tomorrow.*

Maria tells Nils the phone number to snow clearance and they end the call. She makes a quick note in CIF to remind herself to follow up the call in the morning. CIF adds a time-stamp for when the information was entered and asks if Maria wants to activate an alarm for the deadline. Maria quickly confirms the suggested alarm, and then moves on to study the progress reports from the whole region. She uses the timeline feature in CIF to swiftly change perspectives and to compare which old issues caused by the storm have still not been resolved. Maybe Frostby could offer resources to a neighbouring municipality? And what issues are likely to spread to Frostby? Maria follows a link to the website of a local school that has been closed due to the snow. She wants to check when the school plans to open again, but is disappointed. The website only contains an old news item from last week. Why is the information never up-to-date? she mutters to herself.

An hour later Sofia, an interaction designer from CIF, turns off the video camera and gets ready to return to her office. She has been doing an ethnographic study of CIF users as a part of a project to improve the information system, and she has been following Maria for several days during the response work to the snow storm. Sofia is struck by the term "up-to-date" and realises it is only one of many signs of the importance of time in Maria's work tasks. Time, Sofia ponders, was present when Maria was using the timeline in CIF. It was also present in: the time-stamps, the accessing of past notes, the coordination of activities with Nils, writing progress reports, the urgency of time-critical tasks, the organisation of work into shifts, or even in the fact that the phone was used in real time while CIF was used asynchronously. There was no doubt time is something to be considered in the soon-to-be-started design work, but how should they address it?

As the story of Sofia and Maria implies, time influences both how information is presented in a crisis management information system and how the information system interacts with the crisis manager. Crisis management information systems are used by municipalities, and by other authorities and organisations, for diverse purposes, for example, to support information sharing and cooperation. This thesis is about identifying ways to explore the different ways that temporality – different aspects of time – should be addressed in the design of information systems for crisis response and management.

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[1] The story about Maria and Sofia is fictional, but based on the empirical work of this thesis.

2   Introduction

Crises are dynamic, and this has far-reaching consequences for the design of crisis response and management information systems. This thesis explores temporality – that is, any aspect of time – influencing crisis management from an interaction design perspective and offers two tools that are intended to help designers to consider how temporality should be addressed in the design of an interface. In this thesis *crisis* refers to an event that "deviates from the normal and implies a severe disturbance, or an impeding risk for a severe disturbance, in important societal functions and requires immediate action by local and regional authorities" as defined by Swedish law (Justitiedepartementet, 2006). Floods, storms, terror attacks, the spreading of infectious diseases, and other crisis events are dynamic because they change over time. In fact, the whole context around a crisis changes over time. The individuals responsible for crisis preparedness may come and go in organisations. Plans, priorities, work routines, experience, and available information technology support may all change over time. It is possible to list at least five examples of how time is of importance to the design of crisis management systems based on the literature, as summarised in Figure 1.

FIGURE 1 - TIME ASPECTS THAT AN INFORMATION SYSTEM FOR CRISIS MANAGEMENT MAY WANT TO SUPPORT.

First, time has implications for how to present information in an interface. Information visualisation normally addresses how to present large amounts of data so that it can be comprehended and navigated through by the user (Ware, 2008). Visualising information during a crisis is difficult because the opportunities to prepare a visualisation beforehand are limited. It is, additionally, necessary to consider that the visualised information changes over time. Dynamic visualisations are discussed by for example Shannon and Quigley (2010). Second, crisis management is time critical in the sense that decisions need to be made quickly. This implies that information sharing, and consequently information systems support, needs to be fast in order to provide a timely support for the decision making. In crisis management information systems research this is expressed through statements such as "Individual and organisational experiences in the Marmara earthquake taught responsible managers that quick information search, acquisition, and exchange are vital for effective coordination of response operations." (Celik & Corbacioglu, 2009, p 152) or through the frequently occurring "getting the right information to the right person at the right time" (Babitski et al., 2011, p 184; Iannella & Henricksen, 2007, p. 1). Third, one aim of crisis management information systems can be to support situation awareness (SA). SA is an individual's understanding of a situation and how it will develop (Endsley, 1995). The more complete awareness a person - in this case a crisis manager - has of a situation, the more complete is the understanding that decisions will be made on. Time is an important aspect of SA (Endsley et al., 2003, section 2.2) because when the situation changes over time, the operator's awareness needs to change as well. Studying time in crisis situations can therefore potentially lead to a better understanding of the role of time in the crisis managers SA. Fourth, from a cognitive perspective people have difficulties in comprehending temporal relationships (such as, distance in time between events, rates of change in activities, and duration of an activity) (Dörner, 1997). For example, according to Dörner, people have difficulties assessing something that is changing exponentially, and do not have the same immediate overview of all elements as when assessing spatial relationships. Temporal relationships exist also in crisis management, for example, between crisis response activities or events. One activity, such as warning the public about an infectious disease, may depend on another activity, such as monitoring the spread of the infection. The crisis manager may consequently benefit from information system support when trying to comprehend the relationships. Fifth, temporal

relationships can further be studied as a part of coordinating asynchronous response activities. Franke describes the importance of time in coordination of crisis response activities by stating that "The dynamic situation of a disaster also requires that the activities are coordinated according to shifting goals. This means the response evolves over time and it has to be considered what has been done, what currently is going on and what are the next steps." (Franke, 2011, p 23). Franke has developed a process based model for the coordination crisis response activities. He states that actors involved in response activities have shifting goals and priorities and that this makes it difficult to define dependencies between activities beforehand. In the scenario used to illustrate the model, the police, fire brigade, and military are responding to a flood. The police might be responsible for evacuating a residential area, the fire brigade may be building a dam to protect the same area, and the military may be providing sand bags and help in building the dam. As soon as something happens in one of the activities, this may influence what the other actors are doing. Franke's solution to this problem is to allow the crisis managers themselves to define dependencies as needed.

The five elements in Figure 1 explain the importance of time in crisis management and point to areas that are of interest to the design of information technology supporting crisis management. However, even though the overview indicates that time is an important aspect of crisis management, it does not describe how temporality should be addressed during design. The elements in Figure 1 are dissimilar, and the overview does not tell how they are considered in current crisis management information systems or how they should be prioritised.

The following examples offer further viewpoints on that addressing time when designing information technology may influence a person's approach to time. First, Wu has studied how to enhance individual time management by designing personal calendar tools (Wu, 2010) based on temporal structures (Orlikowski & Yates, 2002). Time management is of interest also to the management of crises, for example, to facilitate the planning of response activities. Second, there is a tension between information technology use and the temporal aspects of time-critical work in emergency incident response, meaning that there is a concern that the introduction of new information technology may disturb the response work and lead to, for example, temporal urgency (Landgren, 2007). The outcome of Landgren's study shows that new information technology does not necessarily have negative impact on the response work. In the study, a prototype for providing incident information was tested in an emergency response exercise with the fire and rescue service. The time between the fire crew getting an alarm and arriving at the incident site may be very short, and consequently there were initial concerns that the fire-fighters would not have enough time to retrieve information available in the prototype. Nevertheless, no such problems could be identified when observing the actual use of the prototype in the exercise. The prototype could contribute to the fire crew's understanding of the incident location without signs of temporal urgency or related problems. The examples provide an indication of that there is variety of issues that may need attention when considering temporality from an interaction design perspective. It is unclear how such unlike aspects should be taken into account in the design of crisis management information systems. It is however this complexity that makes the topic so appealing for further exploration.

This section has introduced the research project and motivated why the focus of the thesis is temporality in the design of crisis management information systems. Before continuing to present and discuss the result of the research, a clarification is needed of the major terms and concepts used in the thesis. The following chapters therefore: define the research question guiding the work, provide a background on crisis management, discuss the definition of time, and finally present a thought model that can be used as a foundation for reflecting on temporality in connection with crisis management information systems.

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2.1 PURPOSE, RESEARCH QUESTION, DELIMITATION, AND SCOPE

The purpose of this thesis is to explore temporality in crisis management and study how it can be considered in the design of crisis management information systems. This is summarised in the following research question:

> *How should temporality be addressed in the interaction design of information system support for crisis management?*

The work is delimited in the following way: Information system does in this work refer primarily to information systems used by Swedish local and regional authorities, because of their central role in coordinating crisis management. Temporality is used pragmatically to refer to any aspect of information or crisis management that has a connection to time. Temporal information can, for example, refer to the time, duration, or sequence of events and activities. Furthermore, the focus is on the interaction design of crisis management information systems. This includes how to present information, but also issues concerning the interaction between the users and the system. The objective has been to obtain rich data from a specific group of Swedish crisis managers, in order to build up a thorough understanding of this particular work context and the available information system support, and to identify temporal aspects that can be of interest for the design of crisis management information systems. Even if this is the main target user group, the outcome addresses issues that are likely of interest also from other actors' point of view. The detailed background descriptions of participants and study context in the thesis and appended papers is intended to be a support to the reader in assessing which parts of the outcome may be applicable in other contexts.

2.2 OVERVIEW OF THESIS

The target audience of this thesis is designers and researchers looking for a more structured approach for addressing temporality in the design of crisis management systems. The thesis offers some practical guidance regarding what to consider in design of information systems for crisis management (which is addressed through the suggestion of design principles in Section 5.4) and also offers some support for how to discuss and reflect on time when designing information systems in general (which is done through the thought model presented in Section 5.5). The overview at the beginning of chapter 2 suggests that in order to do this it is necessary to study what aspects of time are of interest to actual crisis management. It is additionally helpful to explore how the aspects are supported by current information systems. This has been done through three interview studies. The outcome from the first two studies contributes to an understanding of how temporality influences crisis management, and also leads to the definition of design principles for how temporality can be addressed in the design of crisis management information systems. The third study focuses on two common Swedish crisis management information systems, and uses them as a basis for an evaluation of the design principles suggested in the previous studies. Crisis managers have an important role as participants in all studies since they are the intended users of crisis management information systems. The method and result are described more in detail later in this thesis.

The thesis is structured as follows:

- Chapter 2 describes the general background of this research project, motivates why the focus is on temporality in crisis management and its implications for interface design, and defines how the outcome can be useful to researchers and designers.
- Chapter 3 provides an overview of crisis response and management and of crisis management information systems used in Sweden. It is possible to address crises and crisis management from various perspectives, and this chapter provides a context for how crisis management is addressed in the thesis. The chapter further contains an overview of common time concepts and describes how *time* and *temporality* are used in this thesis. An emphasis is put on the complexity of the time concept, and what this implies for an exploration of temporality in connection to crisis management

information systems. The chapter ends with a brief introduction to interaction design, and describes concepts from the field that are used in the thesis.

- Chapter 4 describes and motivates the research approach that has been used in the exploration of the research question. It also discusses the different methods used in the appended papers.
- Chapter 5 presents the main result from the appended papers and highlights how it contributes to the overall outcome. The first sub-sections, 5.1 to 5.5, present the outcome, while sub-section, 5.6, reflects on and discusses the outcome.
- Chapter 6 discusses in what ways the outcome answers the research question, and what implication the outcome has for the use of temporality in the design of information technology support for crisis management. Finally, the chapter summarises the main conclusions based on the work presented in the appended papers and describes four possible future research directions implied by the outcome.

3 FRAME OF REFERENCE

Three different areas are of special interest to this thesis: crisis and crisis management, time and temporality, and interaction design. This chapter presents some concepts within each area and reflects on their implications for the conducted research.

3.1 CRISIS

There is no commonly agreed upon definition of crisis (Shaluf & Said, 2003) and a universally accepted definition is unlikely to emerge in the near future (Keown-McMullan, 1997, p 8). Even the same event or situation can be assessed differently by different actors (Boin, 2005; Rosenthal & Kouzmin, 1997; Shaluf & Said, 2003). An early definition of crisis was provided by Hermann in 1972: "A crisis is a situation that threatens high-priority goals of the decision making unit, restricts the amount of time available for response before the decision is transformed and surprises the members of the decision making unit by its occurrence" (Hermann (1972, p 13), also discussed in Rosenthal and Kouzmin (1997) and Keown-McMullan (1997)). This definition has been adjusted by other researchers over time, for example, by Rosenthal and Kozumin, in order to adapt it to a wider context of social, political, and organisational circumstances (Rosenthal & Kouzmin, 1997). Crisis and disaster are closely related, but in general disaster is regarded as a subset of crisis (Boin, 2005; Lerbinger, 1997; Shaluf & Said, 2003). According to Boin (2005), the disaster and crisis concepts are similar but used in different research fields. Disaster is to a large extent used by sociologists and geologists, while crisis is used by public administration, political science and international relations, political psychology, and also by technical specialists such as epidemiologists and information technology experts (Boin, 2005). Boin argues that the fields could learn from each other, and suggests how the two concepts can be brought together. His suggestion is that crisis is connected to the process of perceived disruption while disaster is connected to the collectively arrived-at appraisal of such a process in negative terms. By this, Boin means that a disaster is a crisis with a negative outcome. Lerbinger, and Shaluf and Said do not attempt to integrate the concepts. Both have an organisational perspective on crisis and place (natural) disaster as a subset of crisis.

Crisis in the context of this thesis is, as specified in Chapter 2, based on the definition of an extraordinary event in Swedish legislation, an event that: "deviates from the normal and implies a severe disturbance, or an impeding risk for a severe disturbance, in important societal functions and requires immediate action by local and regional authorities" (Justitiedepartementet, 2006). However, this is only one possible definition. In the *Disaster Research Handbook* Perry summarises and discusses more than three dozen possible definitions of disaster (Perry, 2007) concluding that there is no consensus among researchers for how to use the term. Furthermore, a difficulty is the choice between the closely related terms: emergency, crisis, disaster, and catastrophe. In this thesis, crisis is used rather than emergency. Researchers and practitioners commonly make a distinction between emergencies and disasters, where emergency is the term used for everyday incidents or accidents (Quarantelli, 2000). The definition of crisis used here covers much more than just everyday incidents, and accordingly emergency is a too specific term for the context of this thesis. Quarantelli further mentions that some researchers make a distinction between disaster and catastrophe, where catastrophe is considered the more serious event when "Most, if not all, of the everyday community functions are sharply and simultaneously interrupted." (Quarantelli, 2000, p. 3). Choosing the term catastrophe may therefore be too exclusive considering the definition used here. Boin and 't Hart state that crisis and disaster are often used synonymously (2006). They suggest that a possible distinction is to see a disaster as a crisis with a devastating ending (Boin, 2005; Boin & 't Hart, 2006). By this, Boin and 't Hart mean that not every crisis turns into a disaster and that by studying crises it is possible to learn more about the origin of disasters. This reasoning supports the choice of the term crisis for this thesis, since the definition used here comprises not only events that "deviate from the normal and imply a severe disturbance" but also events that imply an *impeding risk* for severe disturbances.

Transboundary crisis is another concept of specific interest for this thesis. Ansell et al. argues that crises have become increasingly transboundary in nature (Ansell, Boin, & Keller, 2010). A crisis can, according to Ansell et al., be transboundary in three dimensions: *political/geographical*, *functional*, and *time*. A crisis that is transboundary in the time dimension does not have a clearly defined beginning or ending. Examples given by Ansell et al. are 9/11 and climate change. 9/11 is transboundary in time because it has deep running roots, and climate change because it has effects felt years down the road. Crises that cross temporal boundaries are difficult to manage because they may: 1) create uncertainty about when to stand down the response, 2) require first responders to sustain the response for extended periods, or 3) lead to fragmented response, because different functional capabilities need to be mobilised at different times (Ansell et al., 2010, p 197). All the issues mentioned by Ansell et al. have implications for the design of information systems that intend to support crisis management.

3.1.1 Crisis Management

This thesis mainly focuses on crisis management in Sweden, but it should be noted that there are differences in how different countries address crisis response and management. (See for example Britton's discussion of the different background to emergency legislation in New Zealand and Australia (Britton, 2005)). In addition to national crisis management, present day crises frequently have global or international effects and may require international response through, for example, the European Union (Larsson, 2005). When comparing crisis management in different countries, centralisation or decentralisation is frequently used as one of the key aspects ('t Hart, Rosenthal, & Kouzmin, 1993; Quarantelli, 1988). Crisis management in Sweden is distributed and organised according to three basic principles: the principle of responsibility, the principle of consistency, and the principle of closeness (MSB, 2009a; 2011). The principle of responsibility says that the authority that is responsible for an activity during normal conditions has the same responsibility for the activity during times of crisis. The principle of consistency means organisations should, as far as possible, organise their work in the same way during a crisis as in daily work. The principle of closeness states that a crisis should be responded to as close to the affected citizens as possible.

In practice this means that many actors (organisations, authorities, and individuals) become involved in responding to a crisis depending on their area of activity. Response activities consequently require collaboration between different actors. For instance, during a snow storm there will be electricity companies monitoring the power supply, the Traffic Agency and private bus or train companies will all be involved in ensuring that the traffic infrastructure is functioning, and the municipality may be arranging additional shelters for the homeless or for an area that has lost heating for an extended period of time due to the storm. The point is that societal functions are interrelated and there are many different actors responsible for distinct parts of the crisis response. In order to facilitate collaboration, specific authorities are responsible for coordinating the actors responding to a crisis. Municipalities have the main responsibility at a local level, in accordance with the principle of closeness. The county council is responsible for coordination at a regional level when a crisis event is affecting a larger geographic area. The Swedish Civil Contingencies Agency (MSB) is responsible for coordination at a national level. Coordination implies providing general support to actors performing the actual response work.

3.1.2 The Crisis Management Cycle

The different phases of crisis management are often illustrated as a crisis management cycle. The crisis management cycle is defined differently by different authors, but a common approach is to divide the cycle into pre-disaster, during disaster, and post-disaster as done by Aligne and Mattioli (2011), and Sagun, Bouchlaghem, and Anumba (2009). This division is also supported by the findings in a systematic literature review conducted by Lettieri, Masella, and Radaelli (2009) aiming to define the state of the art of the disaster research discipline. Lettieri et al.'s review considers research publications within the period 1980-2006, and part of the thematic analysis in the review discusses the phases of disaster management. The high-level stages are, according to Lettieri et al., commonly divided into four more specific phases: mitigation, preparedness,

response, and recovery. The phases are presented in Figure 2. Mitigation and preparedness are mainly connected to pre-crisis, response is mainly connected to crisis, and recovery is mainly connected to post-crisis. Lettieri et al. note that the phases of the crisis management cycle are interdependent and researchers may divide the cycle into additional (or other) phases than mitigation, preparedness, response, and recovery in order to show specific hazard- and context-related functions. Lettieri et al. have not made a review of how the crisis management process is divided into phases by authorities and practitioners.

A more specific definition directed to the design of information systems is provided by Nieuwenhuis, who divides the crisis management process into *detection, assessment, alerting, mitigation, response*, and *recovery* (Nieuwenhuis, 2007). Nieuwenhuis also suggests *training* as one additional process step that is relevant to information system design. This thesis touches upon issues from all steps in the crisis management cycle, but the main emphasis is on the response phase, as this is where existing crisis management information systems are primarily in use.
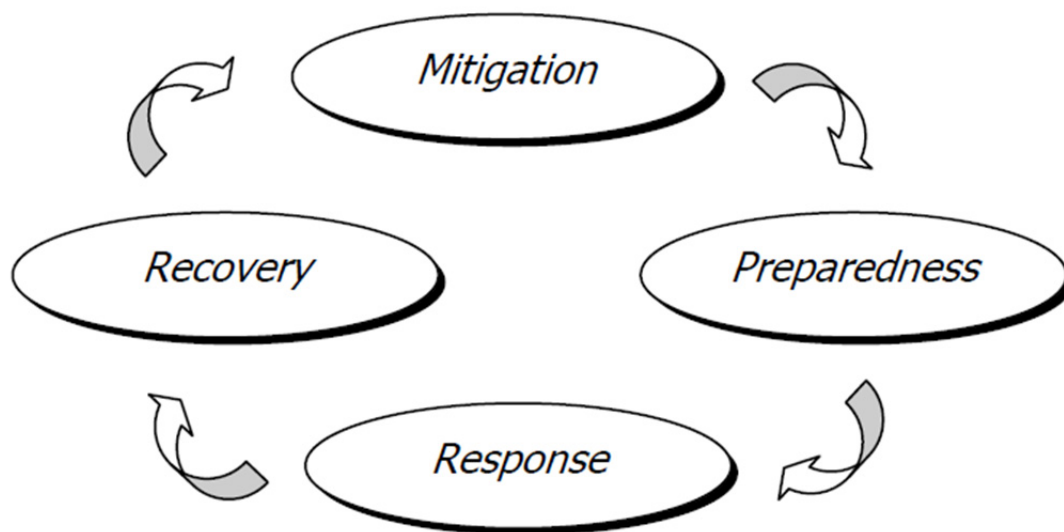
FIGURE 2 – THE PHASES OF CRISIS RESPONSE[2].

3.1.3 INFORMATION SYSTEMS IN SWEDISH CRISIS MANAGEMENT

As mentioned in chapter 2, this thesis focuses on computerised information systems used by crisis managers in local and regional authorities. Three common systems in Sweden are Web-based Information System (WIS), LUPP, and Samverkanswebben (MSB, 2009b, 2010a). WIS is used by local, regional, and national authorities for information sharing concerning crisis management. The windows-based system is to a large extent text-based and information is shared through entries in notebooks and journals. LUPP is used by the rescue service to monitor and document ongoing incident response activities. Samverkanswebben finally is a web-based mashup system collecting information from SOS Alarm, the Traffic Agency, the Police, and other agencies. The main purpose of Samverkanswebben is to present an overview of crisis management related information at a regional level by compiling information on, for example, ongoing emergency response activities, traffic, and weather.

It can be noted that these systems are used in parallel with all other information technology used in daily work by the actors, such as: diary systems, websites, e-mail, phones, and Geographic Information Systems (GIS). Additionally, crisis managers may naturally use whiteboards, pen and paper, and other tools to handle the same kind of information that is stored in the information systems mentioned above.

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[2] Adapted from (Federal Agency Emergency Management, 2011)

3.2 Time and Temporality

Time is complex, and therefore this section explores some of the possible definitions of time and reflects on how they can be utilised in the context of crisis management information systems. Time is often seen as linear and measurable by clocks, or simply as a dimension and part of space-time, but its multi-sidedness becomes clearer when noting the attention it has received by researchers and philosophers over time. Einstein's relativity theory, for example, implies that "simultaneity and instantaneousness can only be defined in relation to a particular frame of reference; that two events which may be simultaneous in one frame may occur at different times in another" (Adam, 1990, p 55). Further, our subjective experience of time can be different from what is measured objectively (Adam, 1990; Wu, 2010, p 3-7; Zerubavel, 1981). Finally, many of the tools and concepts used for addressing time, such as schedules and calendars, are socially constructed and therefore have a subjective component (Zerubavel, 1981). Zerubavel, for example, describes a study of time in hospitals and discusses the different expectations for different professions to take on work tasks outside scheduled work-time. It was assumed that physicians and head nurses would help out if there was a need for their services outside regular work time, but nurses could be said to treat on-duty and off-duty time differently. The nurses could be sitting at their work station when on duty, but also when off-duty in order to finish up administrative work. However, even though the nurses might still be present at the work place after their shift was over, they would not be available to take on any of the regular nursing work tasks. Zerubavel also discusses how calendars are used to divide the time in regular days and special days.

The following definition is used here as a starting point for exploring time:

> *We use our concept of time to place events in sequence one after another, to compare how long an event lasts, and to tell when an event occurs.* (Dowden, 2001)

The above explanation may be close to what designers, developers, and crisis managers have in mind when discussing how an interface addresses time aspects. The quote does, however, not say much about what time *really* is. It is easy to mistakenly believe that people have always related to time in the same way, and that all people relate to time in the same way. From one perspective, time can be seen as a socially constructed concept (Adam, 1990; Zerubavel, 1981). It is not until the beginning of the industrialisation that our concept of time became fully influenced by clocks and exact measurement of time (Sawhney, 2004; Zerubavel, 1981). A common global experience of time evolved even later. The need for a common telling of time did not arise until train travel made it necessary to agree on common definitions (Sawhney, 2004). Even today, alternative calendars, such as the Persian calendar, exist and are used in addition to the Gregorian calendar (which can be considered to be the international standard today) (Zerubavel, 1981, pp 70-101). However, when discussing the definition of time we may also refer to the common experience all people have of that time is passing. Around 350 B.C. Aristotle defines the concept of time in the book of *Physics* by saying that time is: "a number of change in respect of the before and after" (Aristotle, 1996, p 106). Time is a measure of change according to Aristotle. Time is not the same thing as movement or change, but it is that by which movement can be numerically estimated (Dowden, 2001). Aristotle could not decide on whether time could exist independently of any events taking place. That is, if nothing happens at all, does time still pass? This question has been answered differently by philosophers ever since (Dowden, 2001). However, the idea that time is passing and has a direction - the arrow of time - is commonly accepted, as described by Dowden. Events that are in the past have already taken place and cannot happen again. We go from the past into the future. There are different opinions on how this should be interpreted. McTaggart offers two possible views, A-series and B-series of time, but does not believe any of them provides a complete explanation of time (McTaggart, 1927; discussed in Adam, 1990). The A-series is according to McTaggart (1927) the subjective experience of past, present, and future. We always experience both the past and future with the present as a starting point. For example, if thinking back on an event in our childhood, we will have a different perspective on the event depending on if we reflect on it when we are 20 or 70 years old. The difference in perspective happens because all our experiences since the event influence how it is interpreted. The A-series depend on that there is an observer and a "now" that decide how we view time.

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The B-series is different. It does not depend on any observer or any moment that is the present. The B-series looks at time objectively and only makes a distinction between before and after. Any two events can be denoted as one event taking place before or after the other, without any specific reference point being used.

The division between time as it is experienced subjectively by a person, and time that exists objectively and can be measured, is described in various ways by researchers and philosophers. An overview of parallels to subjective and objective time is provided by Wu, (2010), page 4, who has found the following pairs: subjective-objective, quantitative-qualitative, clock-based–event-based, Chronos-Chairos, and linear-cyclical. All these terms denote a similar distinction between subjective and objective time, but are used in research depending on what the researcher wishes to discuss or emphasize. It is additionally important to note that there are researchers who dislike these dichotomies, including for example Orlikowski and Yates (2002) and Zerubavel (1981). Both Orlikowski and Yates, and Zerubavel argue that time can be seen as both objective and subjective, and that both perspectives are necessary to fully understand time that occurs in social activities. Orlikowski and Yates propose an alternative perspective on time, instead of the subjective-objective dichotomy, which sees time as practice-based and "constituted by, as well as constituting ongoing, human action" (Orlikowski & Yates, 2002, p. 689).

Time is often considered in crisis and disaster research when stating the importance of getting information on the right time (Iannella & Henricksen, 2007, p 1) or designing for coordination of crisis response activities (Franke, 2011), but the concept of time is commonly not reflected on much. An exception is the discussion in Kreps (1989) and Quarantelli (1989). Kreps argues that three dimensions of measurement should be used when describing disasters: physical, temporal, and social. When discussing the temporal dimension, Kreps mentions durations, periodicity, and time of origins, which all in all imply a clock-based or chronological perspective on time. Quarantelli, on the other hand, reflects on Krep's use of temporality and suggests that social disaster research should use social time instead of chronological or physical time for coherence reasons.

3.2.1 OTHER TIME-RELATED CONCEPTS

It is not always the concept of time itself that is of most interest to interaction design, but other time-related concepts that can be of practical use in the design work. A number of researchers write about time related concepts that focus on a specific aspect of time. Examples of such concepts are: temporal structures (Orlikowski & Yates, 2002), temporal themes (Lundgren & Hultberg, 2009), slow technology (Hallnäs & Redström, 2001), temporal symmetry (Lee, 1999), and temporal rhythms (Zerubavel, 1981).

Temporal structures does in this thesis refer to the term as defined by Orlikowski and Yates. According to Orlikowski and Yates "time is experienced in organizational life through a process of temporal structuring that characterizes people's everyday engagement in the world" (Orlikowski & Yates, 2002, p. 684). They continue to say that temporal structures are created in this process in order to guide, orient, and coordinate ongoing activities. Examples of temporal structures are schedules, deadlines, financial reporting periods, and seasonal harvests. Temporal structures both shape and are shaped by human activities. One of the origins for Orlikowski and Yates's definition is the theory of structuring provided by Giddens (Orlikowski & Yates, 2002). Other definitions for temporal structures have also been provided by Wu (2010) and by Blount & Janicik (2001). Wu's work is especially interesting to interaction design, since he uses the concept of temporal structures in the development of a calendar tool design to offer improved support for individual time planning.

Temporal themes (Lundgren & Hultberg, 2009) is an interesting concept for interaction design because it addresses how to describe the use of time in an interface. The temporal themes suggested by Lundgren and Hultberg are: live time, real time, unbroken time, sequential time, fragmented time, and juxtaposed time. Lundgren and Hultberg recommend designers to consider time as a design material as this can lead to novel and interesting design solutions compared to if an interface's usage of time is left to be a side-effect of other design choices. Also Redström is considering time in interaction design (Redström, 2001) and argues that time should be seen as the central design variable in the design of everyday computational things. Everyday

computational things as defined by Redström focus mainly on information technology where aesthetics are more important than efficiency, meaning systems used for leisure rather than work. According to Redström, temporal structures are what arise when computational technology executes a program. It is this aspect of computers that make time interesting as a design variable. Redström's work is related to the concept of slow technology (Hallnäs & Redström, 2001). The objective of a slow technology design approach, as defined by Hallnäs and Redström, is for the designs to inspire reflection and to make time visible, in contrast to exclusively striving for efficiency. "Using such an [slow technology] object should not be time consuming but time productive; we should get time for new reflective activities. It is not technology for compressing time to do given tasks, but technology supplying time for doing new things." (Hallnäs & Redström, 2001, p 203). What is interesting about slow technology is that it contrasts to the design objectives for crisis management information systems. Crisis management can be seen as time critical, and in the design of information system support there is a focus on getting the right information at the right time (Babitski et al., 2011, p 184; Iannella & Henricksen, 2007, p 1), while slow technology strives to provide time for reflection. Nevertheless, what the approaches have in common is that they both use technology to guide a user to use available time in specific ways.

Lee uses a definition of polychronic and monochronic cultures developed by Hall (1983) to investigate how information technology affects temporal symmetry of work. Monochronic work here means that work is done in a sequential order one thing at the time, while polychronic means several things are done at the same time. Temporal symmetry is then, according to Lee, when two work teams use the same - monochromic or polychronic - way of working (Lee, 1999). Lee provides two examples where the introduction of new information technology has led to temporal symmetry; one example from a trading company and one example from a radiology department at a hospital.

In *Hidden Rhythms* Zerubavel presents and discusses social time (Zerubavel, 1981). A social perspective on temporality is according to Zerubavel different from, for example, physical or biological approaches in that it looks at the temporal order as a socially constructed artefact. Due to this, more emphasis is put on the subjective aspects of temporality and less on the objective. Zerubavel investigates temporal patterns in situations and events through four parameters: sequential structure, duration, temporal location, and rate of recurrence. He explores various environments and discusses temporal patterns using examples from: hospital life, religion, ideology, and work.

3.2.2 VISUALISATION AND REPRESENTATION OF TEMPORALITY

The research presented in this section can be divided into two groups: research concerning visualisation where the visual representation is not time-dependant, and research concerning visualisations where the representation is time-dependant. The division is suggested by Müller and Shumann and refers to if the visualisation is static or if it changes as the underlying data changes (Muller & Schumann, 2003). Examples of visualisations from the two groups are presented in Table 1.

TABLE 1 – EXAMPLES OF VISUALISATIONS ADDRESSING TEMPORALITY

Time-independent visualisations		
Name	Work	Description
Time waves	Li & Kraak (2008)	Li and Kraak suggest time-waves as a way to represent both the linear and cyclic nature of temporal data. Time-waves can be described as timelines that are not flat, but have amplitude that varies in a cyclical way. The periodicity of the wave can be a year, a day, or any other period that helps describing the data the time-wave is used for. The wave shape of the time-wave intends to facilitate the identification cyclical patterns in the data as a supplement to the linear time representation of a regular timeline. Time-waves can be used in information search to answer questions about if, when, how long, how often, and in what order events have occurred. Attributes of events can also be visualised using shape or colour.

Chronos	Luz, Masoodian, McKenzie, and Broeck (2009)	Luz et al. present Chronos, a solution for visualisation of tasks as an extension of the way Gantt-diagrams are used in planning. Chronos is based on a temporal mosaic which means a timeline is placed on the x-axis and a list of tasks on the y-axis, just like in gant-diagrams. However, the temporal mosaic in Chronos has a fixed height of the y-axis and the allocated tasks expand to fill the whole vertical space.
Continium	André, Wilson, Russell, Smith, and Owens (2007)	André et al. focus on how to display hierarchical relationships in temporal data, and present Continium as a timeline tool that is offering much freedom to the user to interrogate the data from this perspective. André et al. uses classical music related data to exemplify the visualisation used by Continium. Dimensions of classical music can be Era, Composer, Instrument and Piece. All these dimensions have a temporal component, for example: a composer was active during a specific time, a piece was composed or published at a time, and musical instruments were developed at particular periods. According to André et al. other existing tools have problems visualising temporal relationships between dimensions like this, and Continium is an attempt to offer better support of exploration of this kind of hierarchies containing a temporal component.
SemaTime	Stab, Nazemi, and Fellner (2010)	Stab et al. have developed SemaTime, an interactive timeline that visualises both time-dependent data and any user defined semantic relationships. SemaTime presents data with the help of a timeline on the x-axis and domain-specific hierarchical categories on the y-axis. It is possible to both zoom and pan through the data using the timeline navigation features. Semantic relationships are visualised using an arrow between elements and, when applicable, a box stating the time for when the relationship was active.
Time dependent visualisations		
Name	Work	Description
Showtime	Shannon and Quigley (2010)	Showtime is a tool for visualisation of dynamic networks, such as, a person's social network or ad hoc mobile device networks. It includes functionality that adapts the visualisation of the dynamic network so that it can be understood by the user. The speed of the visualisation can, for example, be adjusted depending on how much the information changes at a given moment. The pace can be slowed down when many changes occur in the network to allow enough time for the user to follow them, and speed up for periods when the information is static.
DeepDiffs	Shannon et al. (2010)	Deep Diffs is a tool that visualises the history of a text document. Deep Diffs helps a writer to track changes over time by different highlighting of newer and older edited text

The purposes of the designs vary, and Li & Kraak (2008) is the only visualisation including examples from crisis management. Information in the context of crisis management is often dynamic, which can lead to difficulties when wishing to apply the time-independent visualisations from the first group in a crisis management context. Potential obstacles may be that there is not enough time for user-initiated exploration (assumed for Li & Kraak (2008), André et al. (2007), and Stab et al. (2010)) or that data is diverse and difficult to categorise ahead of time.

Additional visualisation techniques for time-dependent data are presented by Müller and Schumann (2003). A conclusion from the works presented here and by Müller and Schumann is that all the described visualisations are different and often developed with specific situations or data in mind. Based on this, it is not obvious what visualisation techniques are suitable in a crisis management context. Müller and Schumann's advice is that a starting point for deciding how to visualise temporal information is to consider: 1) if the representation is static or dynamic 2) if the time is data or event based, and 3) if a conventional or multivariate display is appropriate.

3.2.3   IMPLICATIONS FOR CRISIS MANAGEMENT INTERACTION DESIGN
The first part of this section has introduced a number of concepts related to time, and it is now time to reflect on how they can be used in interaction design and in crisis management. One of the most obvious traces of time in any information system will likely be based on clock and calendar time, that is, objective and measurable time. It is likely so, because information systems are very good at handling this kind of temporality. Time that is expressed by dates and figures can normally be stored and processed by information systems. Information systems can further add time-stamps, or objectively register the duration of user activities. Objective time is also used in crisis management, since dates and clock-time help people to coordinate

activities. The importance of clock-time is also confirmed by Zerubavel, Wu, and Adam, who mention clock-time as the traditional way to express time when scheduling activities, defining deadlines, or coordinate actions with other people in general (Adam, 1990; Wu, 2010; Zerubavel, 1981). Nevertheless, it is not advisable to focus exclusively on objective time in interface design. As implied by the following quote by Adam, the same point in time can be understood differently depending on which time concept is used when interpreting it:

> *It is not either winter or December, or hibernation time for the tortoise, or one o'clock, or time for Christmas dinner. It is planetary time, biological time, clock and calendar time, natural and social time all at once. (Adam, 1990, p 16)*

Adam is writing from a social theory perspective, but the reasoning may be of use to the design of crisis management information systems as well. The information system designer wants to know how the crisis manager interprets time in connection with events and activities, in order to create interfaces that can represent events and activities in a suitable way. Adam's statement suggests that several different interpretations of time are possible concurrently. This would without doubt cause problems when deciding how an interface should be designed, for example, if we consider the possibility that different crisis managers may have different interpretations of the temporality of an event. Different crisis managers are likely to have different interpretations of the temporality of an event because they have different roles. The response to a chemical accident in a factory can be used as an example. The end time for the crisis response differs for different actors. The ambulance personnel consider the response work completed when the injured have been taken to hospital, the police consider the response work completed when they have confirmed that there was no crime behind the accident, the factory owner considers the response work completed when the production has been restored and the cause for the accident has been investigated, and the municipal crisis manager considers the response work completed when there no longer is any risk for the population near the factory. Further, in clock-based time all time is equal; one hour is one hour long no matter when it takes place (Zerubavel, 1981). To a crisis manager, time is actually not equal in this sense. Waiting one day for a test result may appear fast, if the test usually takes several days, or may appear very slow, if the crisis manager is waiting to make an urgent decision. If a crisis manager makes a ten minutes long call to an expert in another authority to discuss an issue, this has completely different implications if it takes place 14:00 on a weekday or 3:00 in the morning at a time when the expert is not on duty. Consequently, if only clock-time is considered in information systems, then the system may lack support for many of the crisis managers' time-related reflections.

The literature referred to in Section 3.2 has shown that different time concepts are possible, but what would using, for example, clock-based and event-based time mean for the design of crisis management information systems? A crisis management information system based on clock-based time would most likely be similar to existing systems. A system using clock-based time can time-stamp information and activities, and can sort, filter, or present information based on the time attributes, like in the diary function in WIS in Figure 3 (MSB, 2010b).

FIGURE 3 – THE SCREENSOT SHOWS A NOTE CONCERNING A DECISION ENTERED INTO WIS BY AN OFFICER-ON-DUTY. A) TIME-STAMP FOR WHEN THE NOTE WAS PUBLISHED, THAT IS, MADE AVAILABLE TO OTHER USERS. B) TIME-STAMP FOR THE EVENT DESCRIBED IN THE NOTE C) TIME-STAMP FOR WHEN THE NOTE WAS ENTERED INTO THE INFORMATION SYSTEM. D) A LIST OF ALL ENTRIES IN THE JOURNAL, THAT CAN BE SORTED USING THE TIME- STAMPS.

A system designed with event-based time as a foundation would instead consider more qualitative aspects of time as in the Evacuation Management Decision Support System (EMDSS) as in Figure 4 (Lindell, 2011). What is interesting about the EMDSS is that it uses qualitative temporal information, such as: whether there is daylight and what weekday it is, to help the crisis manager to make an estimation of when to evacuate. Daylight time and weekday may influence how long it takes to evacuate, but would not have been considered if the focus was exclusively on clock-time.
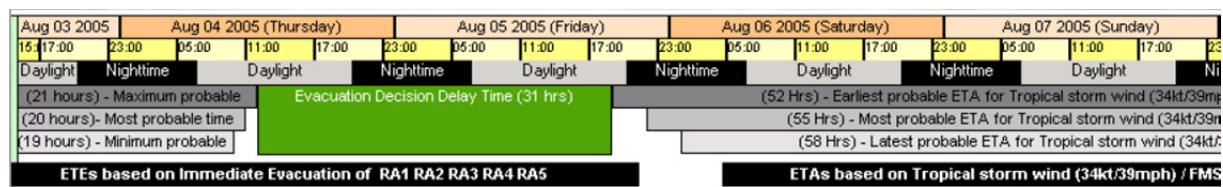
FIGURE 4 – SCREENSHOT FROM AN EMDSS SYSTEM. THE SYSTEM HELPS THE CRISIS MANAGERS TO ASSESS WHEN THEY NEED TO TAKE A DECISION ABOUT EVACUATION.

Normally, a crisis management information system will not be based exclusively on one time-concept, but intentionally or unintentionally use a combination of approaches.

Even when focusing on supporting clock-time, the designer can run into problems. One of the issues is how to represent time from a technical perspective (Allen, 1991). For example, specific date and time for when an event took place might be unknown and consequently not possible to represent. In a crisis management context the duration of a planned response activity, such as evacuating a residential area, might not be known beforehand. Allen suggests different representation techniques depending on if it is possible to use a date-based representation or if only the ordering of events is known. Even though there are numerous ways to represent temporality, Allen notes there are still aspects of how human cognition processes temporality that cannot be readily considered. Persistence assumptions are one such example, that is, the belief that the world generally remains the same from one moment to the next.

To summarise, clock-based time is important when representing time in an information system. However, an information system that only considers clock-time may only partly support how time is used in practice. Both

crisis managers and users in general frequently use event-based or subjective ways of expressing, or relating to, time. What would be helpful to a designer is a way to identify where time-related problems might occur and what time perspectives are interesting.

3.3 INTERACTION DESIGN

Interaction design is defined in the following way by Sharpe, Rogers, and Preece:

> *Designing interactive products to support the way people communicate and interact in their everyday and working lives.* (Sharp, Rogers, & Preece, 2007, p. 9)

Interaction design is, according to Sharpe et al., an umbrella term that includes more specific terms such as: "interface design, software design, user-centred design, product design, web design, experience design, and interactive systems design" (Sharp et al., 2007, p. 9). Interaction design is further associated with a number of different interdisciplinary fields. This thesis does not exclusively stay within one specific field or discipline. The reason for this is mainly that time, as discussed in previous sections, can and should be studied from different perspectives. One field that is important for this work is Computer Supported Cooperative Work (CSCW), see for example (Crabtree, 2003). CSCW is important because crisis management is a collaborative activity where information technology is used by many different crisis managers when responding to a crisis. The thesis is also connected to Human-Computer Interaction (HCI) and Information Visualisation. It is connected to HCI through the focus on design principles, and through the general focus on the interaction between crisis managers and crisis management information systems. The thesis is related to information visualisation because it discusses visualisation of temporal information and dynamic information presentation. All these fields - CSCW, HCI, and Visualisation - intersect to varying degrees.

Design principles is a frequently used term in interaction design and is central for this thesis. Design principles are generalizable abstractions intended to orient designers towards focusing on different aspects of their designs (Sharp et al., 2007, p 29). Design principles could focus on any aspect of design, but in interaction design the focus is often usability related, as in the usability design principles defined by Nielsen (1992). In this thesis the term design principle is used instead of alternative terms such as, guidelines, goals, rules, or heuristics. All these terms are used to express some kind of design recommendations. Both guidelines and rules are used for low-level and specific recommendations (Sharp et al., 2007, p 35; Te'eni, Carey, & Zhang, 2007, Chapter 8) and are therefore not suitable for the kind of high-level recommendations for addressing temporality presented in this thesis. Heuristics and design principles are according to Sharpe et al. more or less interchangeable, but heuristics is the term used in practice - when design principles are applied to a particular problem. Goals, on the other hand, are more commonly used in the context of a specific system that is to be designed or evaluated. To conclude, the distinction between the various terms is not clear, but design principles are here considered to be the best match for the recommendations discussed in this thesis. Design principles of specific interest for the design of crisis management information systems are: the design principles for SA (Endsley, Bolté, & Jones, 2003) and the general design principles for emergency response systems (Turoff, Chumer, Van de Walle, & Yao, 2004). The design principles for SA are significant since an increased awareness of a crisis situation can be assumed to lead to better decision making. The emergency response design principles are important, because the emergency response information systems discussed by Turoff et al. are similar to the information systems described in this thesis. For example, the design principles provided by Turoff et al. have an emphasis on supporting collaboration between many independent actors, which is an issue also in the local and regional crisis management described here. The design principles for temporality suggested in this thesis are intended to be a complement to the existing design principles, since neither of the two existing sets of design principles address temporality in any detail (as discussed further in paper III).

Models are another tool used to guide interaction design work. Common design and HCI related textbooks (Benyon, 2010; Norman, 1998; Preece et al., 1994; Sharp et al., 2007) discuss a wide area of models with diverse theoretical backgrounds and purposes. One possible way to sort the models is to divide them into mikro, middle, and makro-level models depending on their scope[3], as presented in Figure 5.
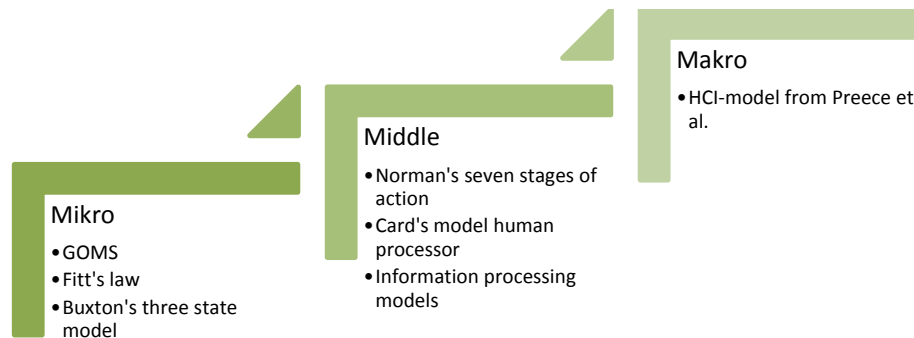
FIGURE 5 – OVERVIEW OF HCI-RELATED MODELS

At the mikro-level there are models focusing on one specific aspect of HCI. For example, predictive models used to evaluate specific aspects of an information systems efficiency, such as, GOMS and Fitt's law (Sharp et al., 2007, Section 15.4). A descriptive mikro-level model is Buxton's three-state model of graphical input (Buxton, 1990). The middle-level models cover a slightly wider scope and include Norman's seven stages of action (Norman, 1998, chapter 2) and Card's model human processor (MHP) (Preece et al., 1994, p 418), which is a historically important example. Information processing models such as the ones discussed in (Preece et al., 1994), section 3.1, and Benyon (2010), Section 24.1 may also be included among the middle-level models. At the makro-level, the models include not only user and computer/machine, but also address use context, as exemplified by the HCI model described in Preece et al., (1994), p. 16.

None of the models in the previous paragraph specifically address the relevance of temporality for a design. Sometimes temporality is implied as in the use of the term "action" in Norman's seven stages of action, and sometimes the purpose of the model is to predict the time it takes to perform a task as in GOMS and Fitt's law, but the models are only of limited help when it comes to understanding what potential impact temporal aspects have for a design and how such aspects practically should be addressed in the design work. Temporality can be found at all model levels, but it is difficult to identify how it actually may influence user, technology, and use context.

When describing the result of this thesis the primarily focus will be on the HCI-part found within the circle in Figure 6. Nevertheless, it is important to note that for crisis management systems the temporality found in the context will have an impact for what interaction design decisions to make. Examples of context is the dynamics of the crisis event itself and the temporality of other actors' activities.

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[3] See Preece et al. (1994), p. 44, for a similar division of analysis levels.
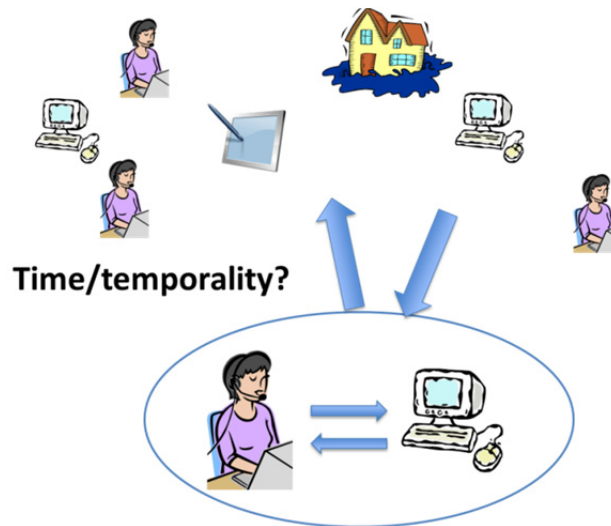
FIGURE 6 – TIME AND TEMPORALITY CAN BE LOCATED BOTH IN THE INTERACTION BETWEEN THE USER AND INFORMATION SYSTEM, AND IN THE CONTEXT AROUND THEM.

This chapter has presented a broad perspective on time and has tried to highlight the diverse ways temporality is discussed in the interaction design related literature. The literature does not provide much guidance on what specific aspect of temporality is most important or what interaction design perspective is most appropriate from a crisis management information system perspective. Chapter 4 describes how the research process of this thesis uses an empirical approach to identifying suggestions for how temporality should be addressed in information system design.

4 METHODOLOGY

This section describes how the research question in Section 2.1 has been approached. The section will first provide an overview of the research process, and then continue to discuss the theoretical aspects of the data collection methods and research process in more detail.

4.1 OVERVIEW OF RESEARCH PROCESS

This research in this thesis uses a qualitative approach and is based on three studies. Together, the studies lead up to the creation of eight design principles and a thought model that can be used to support the addressing of temporality when designing crisis management information systems. The research process focuses on developing theory from the collected empirical data rather than being hypothesis driven. The first study was used to explore potential problem areas, the second study included the choice of temporality as a theoretical lens and the definition of a set of tentative design principles, and the third study assesses and refines the design principles and concludes the three studies by compiling the overall outcome into a thought model.

The first study was planned to be theory driven with an SA basis. SA involves being aware of what is happening around you and understanding what that information means to you now and in the future (Endsley et al., 2003, chapter 2). At the very start, it was clear that crisis management in practice involves much more than just perceiving, comprehending, and projecting a set of environmental information elements, as might be implied if choosing a SA perspective. Such a focus does not consider the whole process for how understanding is created (which might be better explained through, for example, sensemaking, described from an organisational perspective by Weick (1988)) and complex context of crisis response and management with several actors working together and independently on various tasks (even though distributed SA (Stanton et al., 2006) addresses some of these aspects by using a system perspective). The overall question, how crisis situations are understood in general, still seemed to be an interesting direction for the research, considering the objective to identify areas where information technology, or information system, design could be improved. As a consequence of this, the first study was used to explore possible problem areas and to become familiar with different types of crisis managers using case studies and semi-structured interviews. The second study picked up on a few of the ideas that emerged from the first study and explored them in more depth using group interviews. Temporality had not yet been chosen as a theoretical framework, but many issues identified in the first study had a connection to temporality, and specifically to the dynamics of a crisis situation. The participants noted, for example, that when searching for information during a crisis, a large obstacle was when found information was not up-to-date. This was a part of the more general concern about being able to keep track of what is going on in the crisis response work when the status of tasks, activities, what actors are involved in the response work, and the crisis event itself constantly changes. The second study addressed these findings by, for example, focusing on how a crisis manager follows the development of an event, and by suggesting a timeline as support in the prototype that was used as a mediating tool in one part of the group interviews. Based on the first steps of the data analysis, it was decided that temporality would be used as a theoretical lens for the subsequent research. Further analysis of the outcome of the second study resulted in six tentative design principles for how temporality should be addressed in the design of crisis management systems. A third study was then conducted in order to evaluate and improve the design principles based on two common national crisis management information systems. The final step of the research process was to compile a thought model based on the overall outcome of all three studies.
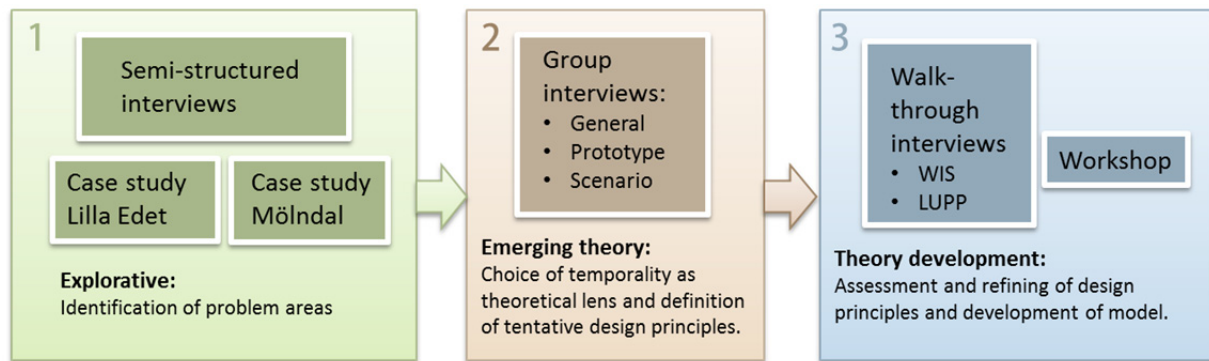
FIGURE 7 – THE RESEARCH PROCESS

4.1.1 Research Process Study I

The first study consists of nine semi-structured interviews and two small case studies. The aim was to become familiar with the crisis managers work situation and to explore their reflections on what support they need, and currently have, in order to be able to comprehend and follow a crisis situation. The interviews were conducted at the participants' facilities, which made it possible to observe their regular work environment. Some of the organisations had specific facilities prepared to function as crisis management centres in case of extraordinary events, which also could be observed, and recorded on photo, in connection with the interviews. The participants were selected from diverse authorities: four municipalities, two county councils, a region, the Traffic Agency, and a rescue service. As indicated by the list, the participants represent local, regional, national authorities, but also different areas of responsibility. The participants were located in three different counties in the south and west of Sweden. The interviews were semi-structured and conducted with the help of an interview guide, but the participants were allowed much freedom to expand on the topics based on their experience, work-roles, and interests. The interviews were voice recorded and partly transcribed based on the interview guide.

The case studies complement the interviews by focusing on two minor crisis events. The first event was an outbreak of calici virus in Lilla Edet in September 2008 (Ekvall, 2010), and the second event a flood occurring in Mölndal in 2006. Both case studies included interviews and collection of publicly available data such as media reports on the events. The disease outbreak in Lilla Edet could be studied directly, and interviews were made both during and after the event. Furthermore, the municipal crisis manager's journal recording the response work was also made available to the researchers for analysis. All the collected data from the interviews and case studies was read through multiple times, and a few main ideas about how information systems could help a crisis manager better understand the crisis situation were noted down to be used as input for the second study. This was primarily done through the creation of a sketch/prototype illustrating the ideas from the analysis.

4.1.2 Research Process Study II

The second study used group interviews to explore more closely how crisis managers follow crisis events and how this can be supported through information systems. The sessions were two hours long to allow for in depth discussion and to allow space for three different approaches to the topic. The interviews were divided into three parts: 1) a general discussion of the participants work tasks and what support they believe may help them in understanding a crisis event and how it develops, 2) a discussion of design opportunities based on a prototype, and 3) a discussion of the workflow during a crisis based on a scenario. The interview sessions were started by a brief introduction of the research project and the agenda for the interview, and permission was requested for voice and video recording of the session. The interviews began by the participants introducing themselves and their roles in crisis management. At the end of the interviews a background questionnaire was handed out and the participants were encouraged to add any reflections and comments they thought had been

missed during the interview. There was also a coffee break scheduled at the middle of the sessions which also allowed for more informal reflections or questions to be asked about the interviews.

The participants were this time chosen from local and regional authorities, since these have important roles in crisis management (discussed in Section 3.1.1). Seven participants took part in the study, divided on two municipal groups with two persons in each group and a county council group with three persons. 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. The groups ended up being small as it was difficult to arrange for times that were convenient for everyone, which is a common issue for group interviews (Krueger & Casey, 2009, chapter 4). Different genders and age groups were represented, and the participant's work roles were also diverse and included: a risk analysts (also working as officer on duty), an investigator, a security adviser, a security coordinator, an information coordinator, an crime and safety officer, and an administrative manager. The intention was that by including participants with different backgrounds in each group, this would create an opportunity for diverse perspectives being made visible.

Mediating materials were used mainly in the second and third part of the interview sessions. In the second part of the interviews, a prototype was used illustrating numerous design ideas based on the overall outcome of the first study. The prototype was created in Serena Prototype Composer, but should be seen as a quick sketch with the goal to visualise the ideas so that they could be explored further. In the third part of the interviews, the scenario was used as a common example in the three groups. The scenario was fictional and based on the Lilla Edet case in the first study and described a waterborne infectious disease outbreak. The scenario was selected because it seemed to be a representative and common event that all participants may become involved in. Ensuring drinking water supply is of specific concern to municipalities as they often are a main supplier of drinking water (National Food Adninistration, 2011). In the interview, the scenario was presented to the participants, and they were asked to describe what activities they would take part in during such an event. The participants were asked to create a timeline on a large sheet of paper using post-it notes to describe the sequence of events their authority would become involved in. During the creation of the timeline the participants were asked to describe what they would be doing in order to follow how the crisis develops, and what kind of support they would expect to be available in order to do this.

The data analysis started by grouping the collected data – voice recordings, photos, the timeline sheet from the scenario part of the interview – by which group it belonged to. The voice recordings were transcribed and coded using open coding. Because the second part of the interviews had a different character, due to the focus on the prototype and interface aspects, it was decided that it would need a separate analysis, and that the first and third part of the interviews would be analysed together. The second part of the interviews was therefore analysed in that all design related suggestions or comments were grouped together based on the previous coding. In practice, this was done by putting all comments in a table and sorting the table so that all comments concerning a common theme were put together. When examining the content of the table, an interesting group of comments concerned the timeline that was one of the features in the prototype. This inspired the decision that the overall focus of the study should be on temporality. The first and third part of the interviews were analysed by identifying those themes that in some way have a connection to how crisis managers obtain an understanding of a crisis. Comments related to this were put into a new table and sorted into different themes. Consequently, at this stage of the analysis there were two tables with data grouped into different themes. The final part of the analysis included a literature review of works related to temporality in connection with interaction design, and this was used in connection with the empirical material to define six tentative design principles describing how temporality should be addressed in the design of crisis management information systems.

4.1.3 RESEARCH PROCESS STUDY III

The aim of the third study was to assess and improve the six design principles from the second study. This was done through walkthrough interviews, which is a combination of walkthroughs and interviews. The participants were asked to present the crisis management information system they usually work with, and to describe in detail how the system has been used during a crisis event that they consider representative. During the walkthrough the participants were asked questions prepared in advance based on the design principles. All sessions were voice recorded, and all but one were recorded on video. This setup made it possible for the participants to comment on issues related to temporality in the context of actual crisis management they previously have participated in. It also made it possible to compare the participants reflections to information stored in the crisis management system, and to observe and record participants when occasionally demonstrating the tasks usually performed in the system.

The objective of the third study was to supplement the focus on the crisis manager of the previous study, and to direct the attention more closely to the design solutions in existing crisis management systems. Exploring how temporality is handled in existing systems was expected to provide feedback on whether there are design issues not caught by the design principles, and to provide design examples that help to illustrate how the design principles presently are supported. This kind of information could then be used to refine the design principles. As a consequence of this, the participants chosen for the study were all users of two commonly used national crisis management information systems, WIS and LUPP (further described in Section 3.1.3 and in paper III). Nine participants took part in the study, whereof five WIS users and four LUPP-users. The WIS users were selected from a list provided by MSB containing all municipalities that were active users[4] of WIS within the county of Västra Götaland. An invitation was sent to all municipalities and the first five positive responses were booked for interviews. The LUPP-participants all work in the same rescue service in a large city area. The reason for this was that it was difficult to find organisations using LUPP regularly. The LUPP-participants' work roles were: head of staff, investigation and analysis officer, command centre operator coordinator, and command centre operator. The diverse work roles meant that the participants use LUPP for different purposes and consequently could contribute with diverse perspectives on the system.

The walkthroughs were planned to be based on common user tasks defined based on user manuals and training material. However, in the first interview it was clear that the users of the systems use them for diverse goals, and that they do not use the same parts of the systems and are not familiar with the same types of tasks. Because of this, it was decided to allow the users to focus on a crisis event they consider representative for how they use the system and to use that as a basis for the exploration. Another mediating material was the questions which had been prepared based on the design principles. This was done by first examining the rather abstract design principles, and then rephrasing them into more specific questions better adapted for use in an interview context. Most design principles could be rephrased into more than one question focusing on different aspects of the design principle.

The data analysis started with careful transcription of all voice recordings. The video recordings were re-watched in order to identify design examples for later use as illustrations when discussing and presenting the result. The transcripts were then coded using the design principles as labels, plus one additional label for any other comment related to temporality but not directly connected to the design principles. All comments with a label were then sorted into a table grouped by design principle and by information system. Each group was then analysed for common themes, and notations were made in a separate column for comments of specific interest or which implied possible improvements of the design principles. The outcome of the analysis was the suggestion of two new design principles, but also a better understanding of the different types of feedback which can be obtained with the help of the design principles. The design principles were further refined through a workshop with MSB-personnel. A final step of the research was to compile the outcome of the three

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[4] Users are considered active if they have logged in into WIS at least once during the past 6 months.

studies into a thought model that can be used in connection with design work to explore issues related to temporality. This was done iteratively over a period of several months, with frequent informal feedback from researchers active within crisis management, interaction design, and HCI.

4.2 INTERVIEWS

Interviews are the primary data-collection method used in the studies included in this thesis. The data-collection has, however, not been performed in the same way in the three studies. Three diverse interview techniques (see Table 2) have been used: individual semi-structured interviews, group interviews, and walkthrough interviews. Interviews were chosen as method, because crisis managers' reflections are highly interesting for the design of information technology supporting crisis management. Crisis managers are potential users of the technology and domain experts, having more practical experience of crisis management than designers and researchers in general. Interviews are one way to become informed about their knowledge and experience. When conducting interview studies it is important to consider that the interview statements are the interviewee's description of the interview topic (Gillham, 2008, Chapter 1; Silverman, 2005, Chapter 4.2 and Chapter 11.3.). Interview statements are, according to Gillham and Silverman, influenced both by how the interviewee's personal perspective on the interview topic and by the context of the interview situation. This is normally addressed by: considering in what ways subjectivity and context may influence the result (Gillham, 2008, p 23), and by comparing interview statements to other sources (Silverman, 2005, p 154) which leads to increased validity through triangulation. Both approaches have been used in this thesis.

Interview method	Applied in	Advantage	Potential problems
Semi-Structured interview	Paper I	Easier to set-up compared to group interviews and walkthrough interviews. Direct access to participants (compared to surveys). Uses a combination of closed and open questions. (Dix, Finlay, Abowd, & Beale, 2004; Gillham, 2008; Sharp et al., 2007)	The interview result depends on both interviewer and participant, and requires that the interviewer is aware of interviewer bias and how to guide the interview. (Dix et al., 2004; Gillham, 2008; Sharp et al., 2007)
Group-interviews	Paper II	Can be time-saving since several persons are interviewed at the same occasion. The interaction between the participants can provide additional information that is not detected in individual interviews. (Frey & Fontana, 1991; Gillham, 2005)	A group is more difficult to schedule, requires discussion leading, and it is harder to analyse recordings with several speakers. Specific individuals may negatively influence the discussion. (Frey & Fontana, 1991; Gillham, 2005)
Walkthrough interview	Paper III	Has the potential to increased validity compared to regular interviews, since the participants statements can be compared to the information content of the system and their demonstration of tasks. Can be more realistic compared to regular walkthroughs since actual tasks are described.	This specific method combination has not been tested before. Requires much preparation. Only useful if system stores information about past usage. The interview is done in retrospect and consequently observations of actual usage can offer more information on how the interface is used.

TABLE 2 - SUMMARY OF INTERVIEW METHODS USED IN THE THESIS

Semi-structured individual interviews were used in the paper I. This is a more traditional interview method compared to the methods used in paper II and III. An interview guide with open questions was used to set the direction of the interview, and the participants' comments were followed up by additional questions where clarifications or further exploration seemed beneficial, as recommended in Berg, (2009), pp 107-109. The aim of the interviews was to elicit information requirements for information system design and to obtain an initial understanding of the crisis managers' work. Participants were chosen from many different authorities in order for the interviews to be a broad introduction into the field and to cover diverse perspectives. The nine interviews were combined with case studies and reading of crisis management plans and regulations. This combination of methods contributes to increasing validity of the interview result through triangulation since the case studies present an additional perspective that the interview participants reflections can be compared

to. (In accordance with what was recommended by Silverman, see previous paragraph. In qualitative research triangulation is assumed to increase credibility and confirmability (Guba, 1981; Guba & Lincoln, 1982).) The content of a crisis manager's journal from one of the case studies could, for example, be used to either support or contradict what had been said in the interviews, and knowledge of regulations and planning can help in understanding the context for why the participants have answered in certain ways or suggest follow-up questions during the interviews.

Group interviews were used in the second study in order to explore how information systems are used in crisis management through a more informal discussion compared to the interviews in the first study. The discussion was focused on specific topics through the help of a prototype-sketch of a possible information system and a scenario of a waterborne infection. The discussion additionally included a general introduction part where the participants could describe their own experience of crisis management and crisis management information systems, as a necessary background to the later parts. Altogether the discussion included three parts. (For more details on the usage of prototype and scenario see the appended paper II.) In this study there were only three interviews, but the interview time was set to two hours in order to allow in depth discussion. The objective was to use the discussions in the group interviews as a basis for deciding what specific crisis management information system design aspects were most interesting for future research. The result of the study indicated the importance of time and temporality, and lead to the definition of the first design principles for temporality. Group interviews were chosen in order to take advantage of the group dynamics that are present when several persons are interviewed together (Frey & Fontana, 1991; Gillham, 2005, 2008). Frey and Fontana argue that group interviews can indicate a range of views among the participants. Further, according to Gillham, group interviews may reveal dynamics through interaction and issues not apparent in individual interviews. In the group interviews used in study II, triangulation was achieved in three different ways: 1) three groups were used in the study, 2) the work roles of the participants within each group were diverse, and 3) each discussion included three different ways to address the topic. Using three groups means that results can be compared between groups. Different work roles within the groups opens up for diverse perspectives being covered in the discussions. Using three ways to approach the topic in each interview also increases the likelihood to obtain a more comprehensive result. A weakness of this interview set-up is that the group interviews included too few participants (the number of participants was three, two, and two) to be regarded as full focus groups. The recommended number of participants in a focus group in order to optimize the discussion is 5-10 participants (Krueger & Casey, 2009). On the other hand, fewer participants in the interviews makes it easier for the moderator to guide the discussion and makes analysis of recordings easier (Gillham, 2008, Chapter 9). Mini focus groups are further discussed by Edmunds who discusses triads (focus groups including three participants) and dyads (focus groups including two participants) (Edmunds, 1999, pp. 19-22). According to Edmunds the advantages of tryads are: 1) they allow greater detail with more in-depth probing on topics of discussion, 2) They permit enhanced testing of new products and procedures, and 3) the format cuts some costs generally associated with larger groups. All three advantages apply to the study of paper II. Edmunds also lists the following disadvantages: 1) The triad format requires conducting more groups to obtain enough information for analysis, 2) the format limits the variety of opinions offered; fewer opinions are available unless more groups are conducted, and 3) triads require a strong moderator to minimize participants' discomfort. Disadvantage number one and two are connected. In the study of paper II three groups were used, and this generated enough data to allow an informative analysis. However, it is clear that even more could have been learnt from the study if more groups had been included. In the context of this research project, the rather low number of groups has partly been compensated in that additional participants could contribute to the evaluation of the result through the study of paper III. The third disadvantage mentioned by Edmunds may be a concern since the moderator was inexperienced in leading focus groups. Precautions were taken to prevent this issue by running a pilot study before the actual focus groups.

Walkthrough interviews were used in the third study. This new combination of methods arose as a way to address that it was not possible to study actual usage of crisis management system live. The walkthrough

interview is related to the stimulated recall method (Busse & Borromeo Ferri, 2003; Dempsey, 2010). However, in stimulated recall video recording is used to capture an activity, and the participants are later asked to recall and retell what they were thinking when doing the activity. The method aims to provide insight into the internal processes of the participants. It can be combined with a regular interview after the recall phase in order to consider the participants reflections on what was going on during the activity, since reflections are normally not encouraged during the recall phase (Busse & Borromeo Ferri, 2003; Dempsey, 2010). In the walkthrough interviews the information stored in the crisis management system was used to stimulate recall, instead of a video recording of the activity as in the stimulated recall method. Further, there was no separate recall phase, but the participants described what had been done during the crisis response work as would have been done in a traditional retrospective interview. The walkthrough interview is nevertheless similar to the stimulated recall method, since it also aims to obtain some insight into "the process of working on a task without interfering with the process itself" (Busse & Borromeo Ferri, 2003, p 257). The walkthrough interviews can be seen as overlapping methods supporting the dependability of the result as described in Guba (1981). The aim of the interviews was to evaluate previously defined design principles for temporality, and doing so based on actual crisis management information systems[5]. One possible way to approach evaluation of design principles is to use heuristic evaluation (described in for example Nielsen (1992) and Preece et al. (1994)) or a walkthrough method (described in for example Dix, Finlay, Abowd, & Beale (2004) and Lewis & Wharton (1997)). The advantage of using walkthrough interviews instead of heuristic evaluation or a regular walkthrough is that it brings the evaluation closer to how the information systems are actually used, both because the interfaces are tested in the field and because actual users can contribute with explanations and demonstrations of the interface. The walkthrough interview used in study III was set-up as follows: Preparation included creating user tasks for the information systems included in the study. The tasks were based on user manuals and training material in order to ensure that the focus is on common and representative tasks. Questions were also prepared based on the design principles and were used throughout the interview. In the data-collection, it was planned that the participants would step through the prepared tasks and discuss the information system based on the design principles. It was, however, clear in the first interview that the crisis managers participating in the study use the systems in dissimilar ways. They do not use the same functionality and have diverse overall aims of when and how to use the system. Due to this, the participants were asked to suggest tasks that they consider representative of how they have used the system, instead of using the predefined tasks. A potential problem with allowing the participants to select tasks or events to discuss is that they may be choosing: only positive examples of information system usage, only examples where there were large problems with using the systems, or only examples that are easy to explain and that do not illustrate complex aspects of the system usage. The first two problems could arise simply because these are examples that easier come to mind, or because the participants intentionally avoid some examples. For the aim of paper III it was not crucial that all possible examples of tasks and events are covered, as long as the example is comprehensive enough to be a basis for a discussion about issues related to the design principles. A recommendation when allowing the participant to select examples for discussion is to ask the participant to explain why they chose a specific example. The motivation can then be used to better interpret the result, and to note what may be missing in the result. In paper III several different examples were discussed in each interview to make sure that the result does not depend exclusive on one unique case. The participants were also asked questions about the context of the example so that the example can be put into relation with their work tasks in general. Nine participants took part in the study divided on two information systems (five respective four users on each system).

To conclude, walkthrough interviews allowed observation and voice and video recording of: 1) information from actual crisis events stored in the systems, 2) the participants reflections on the temporality of interface and stored information based on the design principles, and 3) participants demonstration of tasks as a part of the discussion. A walkthrough interview cannot provide the same kind of observations of how a system is used

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[5] The systems in the evaluation have not been developed based on the design principles for temporality.

as user studies (where actual usage of a system is observed (Sharp et al., 2007)). Nevertheless, a walkthrough interview offers additional information compared to a regular interview. In a walkthrough interview the participants' reflections can be compared to the information that is stored in the system, and to what is observed as the participants demonstrate tasks or describe how the system has been used in an actual event. This kind of interview can be assumed to be especially useful when it is not possible to observe actual usage of the system and when the information system stores information, and other traces, that imply how the system has been used.

4.3   CASE STUDY AND WORKSHOP

Case studies and a workshop have been used more informally, compared to the interview methods described in Section 4.2, for data-collection in the work underlying this thesis. This means that the case studies in paper I and the workshop in paper III mostly have been a supplement to other methods. Two case studies were conducted in the study of paper I, one about an infectious disease outbreak in a municipality and one about flood in another municipality. The case studies in paper I can be described as instrumental (from Stake (2000) discussed in Berg (2009) and Silverman (2005)) and exploratory (Berg, 2009; Yin, 2009). They are instrumental because the aim was to learn about crisis management and about the usage of crisis management information systems, not only about the single cases as in intrinsic case studies. They are exploratory because they were used at the beginning of the research project as a part of identifying topics for further research. The case studies were small and included interviews, reading about the crisis event in media, and collecting documentation such as the crisis manager's journal describing the response work in the first case. If redoing the study of paper I, a more empirically based approach would have been to extend the case studies, and reduce the number of interviews also included in the study. The reason for this being that the case studies offered more opportunities to study actual crisis management compared to the more general interviews. This could have allowed for a grounded theory-approach as described by Berg (2009, p 319-321) and helped identifying issues suitable for further study. Theory driven case studies (Berg, 2009; Yin, 2009) would not have been appropriate here, since no predefined theory suitable for testing was available this early in the research process.

The workshop in study III was originally not intended to be formal data-collection in the project, but has contributed as a member check on the data from study II. Member checks are when data and interpretations are tested with audiences and groups from which data are solicited (Guba, 1981; Guba & Lincoln, 1982). The workshop included eight participants involved in design projects of crisis management information systems at MSB. The outcome of the workshop was very useful in the evaluation work of paper III, and in retrospect the workshop could have been more carefully planned in order to provide even more feedback. An analysis should have been made before the workshop defining specifically what kind of feedback would be essential to study III.

4.4   REFLECTION ON RESEARCH PROCESS

The research process is overall qualitative and has been exploring how temporality can be addressed in crisis management information system design through close collaboration with users of this kind of systems. One of the major methodological obstacles is that it is difficult to observe crisis management in real time during actual crisis events, even though there are researchers doing longitudinal ethnographic studies (for example, Forsman, 1997; Oliver-Smith, 1992; Shklovski, Burke, Kiesler, & Kraut, 2010). Crisis events occur rarely, and several of the crisis managers participating in the studies stated that it was several months or years since they last managed an extraordinary event. This implies that researchers depend on methods such as interviews or trying out design ideas in exercises. There is a risk that interviewees cannot provide a correct account of how they use crisis management systems in actual crisis events, and activities observed in exercises or training might not always reflect what would happen in an actual event. In the research conducted in this thesis we have worked around this issue in a number of ways. In the study of paper III, actual crisis management was

studied through the examination of information in existing crisis management information systems. In the study of paper I, a crisis manager's journal notes were available as a more objective account for the response activities in the Lilla Edet case. Furthermore, interviews could be conducted both during and after the actual response work. The crisis managers interviewed in the studies presented in this thesis contribute with an important perspective because they are domain experts and end-users of information technology supporting crisis management. Nevertheless, when interpreting the outcome of this work, it is necessary to keep in mind that there might be additional viewpoints that could not be covered through this research approach. One example is that crisis managers' answers are influenced by the specific crisis response they have participated in. This makes it important to learn from differences in reflections between interviewees who have experienced different kind of response work.

Transferability (Guba, 1981; Guba & Lincoln, 1982) has been considered in the studies by providing detailed information on participants and context. This has been done by describing participant background in the appended papers, and by describing the crisis management context in the background section of this thesis. This kind of information can according to Guba be a support when trying to assess how the different parts of the result may apply to other cases. The descriptions of participant backgrounds in the appended papers include information on, for example, what kind of organisation they work in, their work roles, gender, age and years of experience.

Theoretical sampling has been used for selecting the participants, and the process can be followed in Section 4.1. The participants in all studies were selected with an emphasis on local and regional authorities due to their important role in crisis management (see Section 3.1.1). Most of the participants work in organisations that can be seen as representative for Swedish authorities in general, and were not chosen in order to illustrate any unique cases of crisis management. Unique features of the participating organisations have been pointed out when possible. The county council in paper II is for example special, because it is situated in a big-city area and by the coast, which implications are discussed in the paper. The participants in the study of paper III were selected because they were users of existing crisis management information systems. In the first study, paper I, the selection of participants was broader in order to get an overview of how diverse actors participate in crisis management as an introduction to the subsequent research. Theoretical saturation (Bowen, 2008; Glaser & Strauss, Anselm, 2004, p 229; Guest, Bunce, & Johnson, 2006) has been used as a guide for when to stop looking for additional participants for all studies. In retrospect this has been successful except for in paper III, where saturation may not have been optimally obtained. Paper III involved participants from municipalities and rescue services using the information systems, WIS and LUPP. All LUPP-users came from the same rescue service, and it can be assumed that additional information could have been obtained if the study had included participants also from other rescue services. The rescue service participating in paper III is located in a large city area, and it is possible that LUPP usage might be different in other regions of Sweden. Nevertheless, the difference between the participating rescue service and other rescue services, for example regarding the use of command centres, was reflected on in the interviews and considered when analysing the results.

Possible improvements to the research process would have been to do the case studies at the beginning of the paper I in a more comprehensive way. The case studies were an excellent opportunity to get rich data as a foundation to the future work, but the emphasis was put on the nine interviews also a part of paper I. The study in paper II was structured in a more comprehensive way, but would have benefited from more participants in each interview group. The interviews lead to very informative discussions, but if the number of participants had been around six, instead of two and three, the interviews would have had the advantages of focus groups (Krueger & Casey, 2009). Furthermore, the prototype used in paper II had a very small role in the study. If there had been time for a more thorough design process, the prototype could have received a more significant role and possibly directed the research towards a more design oriented path. The study in paper III has contributed well to a validation of the design principles. One clear shortcoming is that all participating LUPP-users were employees at the same rescue service. A foremost reason for this is that few fire and rescue

services use LUPP. There was a tenth interview planned with an employee from a different fire and rescue service but it could not be conducted in time to be included in the paper.

5 SUMMARY OF RESEARCH AND CONTRIBUTIONS

This chapter first presents the individual contributions of the papers and then the overall contribution of the research.

5.1 PAPER I - DESIGN REQUIREMENTS FOR INFORMATION SHARING IN A CRISIS MANAGEMENT COMMAND CENTRE

The study in paper I included two case studies and nine interviews. The main objective of the study was to learn more about how crisis management is organised in Sweden, and how it currently is supported through information technology. The case studies investigated two small crisis events near Gothenburg: one case of waterborne disease outbreak, and one case of flooding. The interviews were semi-structured with participants from different organisations: municipalities, county councils, the Traffic Agency, one region, and one rescue service.

The contribution of the first study is a description of how crisis management is organized at a local and regional level in Sweden. Conclusions drawn regarding the design of crisis management systems are that: information systems need to be usable in the daily work of an organization, information systems need to be adaptable to the diverse working conditions in different organisations, and finally information systems should be interoperable with different kinds of information sources. The result also lists three different types of information that the crisis manager needs to have access to or be aware of: facts about the crisis, information about recourses, and documentation (for example, decisions, plans, meeting minutes).

5.2 PAPER II - TEMPORAL ASPECTS IN CRISIS MANAGEMENT AND ITS IMPLICATIONS ON INTERFACE DESIGN FOR SITUATION AWARENESS

The study in paper II was conducted through three group interviews with a total of seven participants. The aim of the described study was to learn more about what crisis managers do to follow a crisis event and how information systems are used in the process. The topic was approached from three different perspectives in each interview. The interviews started with a general discussion about how the participants work and what information sources they use in their work. The middle part of the interviews focused on a prototype, or sketch, illustrating a range of possible ways to support the user's understanding of a crisis situation. Finally, the third part of the interviews focused on a scenario. One of the groups consisted of three county council crisis managers, and the other two groups consisted of two municipal crisis managers in each group. The group meetings were two hours long, in order to allow for comprehensive discussion.

The thematic analysis of the interview transcripts suggested that temporality is an important topic to consider when designing information technology support for crisis management. The interview result was therefore used as a foundation for eliciting six design principles on this topic. The design principles focus on how temporality can be considered in the design of information technology supporting crisis management. The principles are based on both the empirical material and on related work and theory.

The contribution of the second study is the following six design principles for how to consider temporality in the design of information technology for crisis management:

1. Make temporal relationships between asynchronous activities salient;
2. Make information about past crises, and past crisis management events in ongoing crises, easily accessible;
3. Add create/last-modification time-stamps to information;
4. Indicate how events and activities may develop;

5. Support alternative temporal scaling; and
6. Give support for emerging information sources.

The design principles are further described in section 5.4

5.3 PAPER III - EVALUATING DESIGN PRINCIPLES FOR TEMPORALITY IN INFORMATION TECHNOLOGY FOR CRISIS MANAGEMENT

The aim of the study in paper III was to start an evaluation the design principles suggested in paper II. This was done by using two common Swedish information systems, WIS and LUPP, as a basis for nine interviews with crisis managers in municipalities and fire and rescue services. The participants were asked to show information from one or more actual events that they consider representative for how they work with the information system.

While doing this, the participants were asked to reflect on the interface and information based on predefined questions focusing on temporality. The questions were based on the design principles, but had been rephrased to be fitting to an interview situation. They were asked in no particular order, but were included depending on what specific part of the interface and work tasks the participant was talking about. Through this, it was possible to compare the participants reflections about the crisis management to the information stored in the system. During the interviews the participants occasionally demonstrated common tasks in the system as a part of their explanations. Since the interviews were voice and video recorded, both the demonstrations and design examples from the interfaces could be caught on video. The interviews were transcribed and then coded using the design principles as labels.

The contribution from the third study is threefold. The outcome confirms that the design principles: 1) can be used to identify design flaws in an crisis management information system, 2) can be a foundation for discussion about how temporality is presented in the interface, and 3) can inspire discussion about temporality in relation to the design in general. Furthermore, the evaluation suggests two additional design principles as a complement to the original six:

7. Support the pace of the users' tasks and work; and
8. Allow for different users being responsible for the same tasks over time.

The additional principles broaden the perspective towards a CSCW direction.

As a final step of the data-collection, the findings were presented to a group of MSB personnel in an informal workshop. The objective was to receive feedback on the findings as a part of further assessment of the design principles usefulness in design. The eight participants were all connected to MSB's own development projects of crisis management information systems. Half of the one-day workshop was spent on presenting and discussing the design principles and the findings from the interviews, and the other half was spend on MSB presenting their information system development projects. The result of the workshop confirmed that the design principles address relevant topics. The participants provided examples supporting that issues regarding temporality are discussed during actual design work. The participants agreed with the content of most of the design principles, but had objections about the importance of providing past information (design principle 2). The overall goal for the MSB crisis management information systems is to provide support for ongoing events. Due to this, the participants mentioned two reasons for not providing historical information: 1) the information may distract the crisis manager from the ongoing event, and 2) historical information may not be relevant to the ongoing work, because the context will have changed since the previous crisis event, for example, regulations, liaison officers, and other factors may be different. More details on this discussion can be found in paper III.

5.4 DESIGN PRINCIPLES FOR TEMPORALITY

The design principles for considering temporality in crisis management information system design have been described in more detail in paper II and III. A summary of the design principles is presented in Table 3:

TABLE 3 - SUMMARY OF DESIGN PRINCIPLES

	Design principle	Comment
1	Make temporal relationships between asynchronous activities salient.	Temporal relationships here refer to the relationships between response activities (evacuation, taking care of injured, restoring infrastructure, informing, and other activities) that may be executed by different actors. Temporal relationships describe if activities go on concurrently, overlap, or depend on each other in other ways. This information is useful to the crisis manager when planning and organising the response work.
2	Make information about past crises, and past crisis management events in ongoing crises, easily accessible.	Information about past events can support the crisis manager in understanding how to manage the ongoing crisis event better, for example, by describing response approaches that previously have been successful or unsuccessful.
3	Add create/last-modification time-stamps to information.	Time-stamps are an important way to translate temporal information so that it can be processed by an information system. Time-stamps can be created for the time when information was entered into the system. If the information concerns an event or activity, then it might be interesting to additionally provide time-stamps describing the event or activity.
4	Indicate how events and activities may develop.	Prediction of how a situation will develop is an important part of SA. It is possible to support an understanding of how events and activities may develop in different ways, for example, by presenting how a parameter historically has changed over time or by more advanced simulations.
5	Support alternative temporal scaling.	Different work tasks may require the crisis manager to look at information from different temporal perspectives. Depending on work tasks the crisis manager may want to see information concerning a specific event, a specific day, or a specific year. The system can either allow the crisis manager to change how information is presented or automatically adjust the time scale when possible.
6	Give support for emerging information sources.	During a crisis, information sometimes comes from unexpected sources. That is, sources that were not known at the time when the information system was developed. New databases created for use in the response to a specific event is one example of emerging information sources that an information system may want to obtain information from.
7	Support the pace of the users' tasks and work.	The system should work at a pace that is suitable considering the users' tasks, since the information technology may otherwise disturb the work flow. A crisis manager can for example be distracted by alerts, phone calls, or other events that require attention. The crisis manager may also have to wait for information or feedback from the system if update times are slow.
8	Allow for different users being responsible for the same tasks over time.	Crisis management can go on for more than one working shift, and consequently the same role may need to be executed by different individuals. If so, the information system should support this kind of work division. Further, crisis preparedness or work may go on for a long time or even continuously, which implies that an information system need to allow for that users in general will come and go in an organisation over time.

The first six design principles are primarily focused on how temporal information is presented, while number seven and eight are more connected to system behaviour and interaction between system and crisis manager.

5.5 Thought Model Supporting Exploration of Temporality in Information System Design

The thought model presented in this section is intended to be a support when addressing temporality in the design of information systems. The thought model can be used as a foundation for exploration of where temporality should be considered in interaction design. The thought model is based on reflections on the overall result from the three appended studies, but addresses issues that can be of interest for information system design in general.

The HCI-model (mentioned in section 3.3) will be used as a starting point for identifying what temporality is of interest to the design of information systems for crisis management. Focusing on the user, information system, and the interaction between them provides a good starting point, since it helps identifying issues that are of actual importance to interaction design. A simplified version of the HCI-model, adapted from Preece et al. (1994), p. 16, is presented in Figure 8.
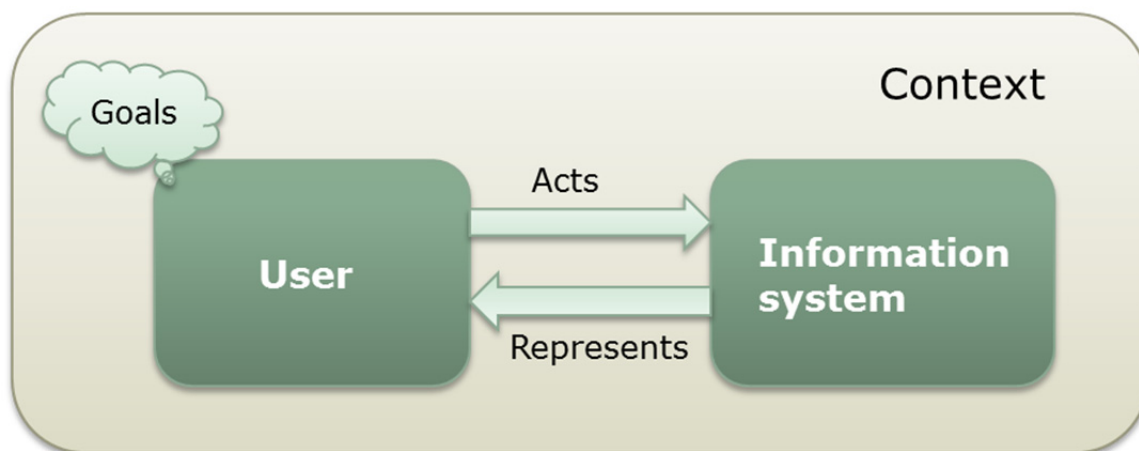

FIGURE 8 – HCI-MODEL, SIMPLIFIED ADAPTATION

When analysing the design principles from section 5.4 and the overall outcome from the three studies two distinct perspectives on temporality can be identified. It is here argued that **temporal information** and **temporal action** can be used as a basis for exploring how temporality influences the interaction between human and information system. By *temporal information* is here meant any information that has a temporal component, for example, references to dates, durations of activities, or changes in the crisis event. By *temporal action* is meant any temporality found in the actions of the user or the system. This is, for example, the times and durations of the user's working shifts, the processing speed of the information system, or the regularity of information system updates.

A user *comprehends* the temporal information presented by the system, and the system processes and re*presents* the temporal information provided by the user (Figure 9). For instance, a crisis manager (=user) enters a status report into a crisis management information system (=system). The report can include several references to temporal information, such as the time for different response activities. The report is also entered into the system at a specific time. These temporal information elements need to be represented in different ways by the information system. Correspondingly, any temporal information that is represented by the system needs to be comprehended by the user. This highlights two possible problem sources regarding how temporality is used by user and system. Problems can arise that relate to both representation and comprehension. For example, a system might have problems representing temporal information because the information is missing. The exact time for when a storm will hit a geographic area might not be known. (Compare with the discussion in Allen, 1991.) Similarly, the information system might present the specific date and time for a crisis response activity, but this representation might not be suitable because the crisis manager

may be thinking of the activity as taking place "last weekend" or even "when Sven was acting as officer-on-duty". The representation is then not in accordance with how the crisis manager comprehends the temporal information (compare discussion of the concept of time in Section 3.2). Comprehension of temporal information can also depend on whether the time scale is appropriate considering the user's goals. When responding to a major land slide blocking a road, the municipal information officer is likely to want the latest news and follow the first responders' activities, while the security coordinator may be involved in doing a risk analysis for the future based on historical information together with experts from other authorities. Their needs concerning how temporal information is represented may consequently be diverse.
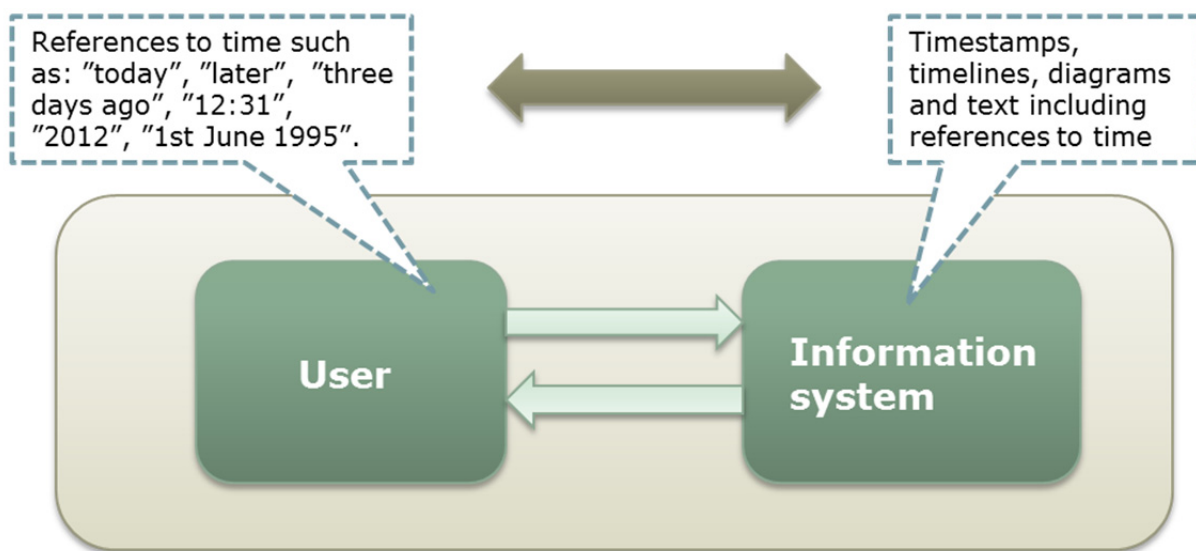

FIGURE 9 – USER NEEDS TO COMPREHEND TEMPORAL INFORMATION PROVIDED BY THE SYSTEM, AND SYSTEM NEEDS TO PROCESS AND REPRESENT TEMPORAL INFORMATION PROVIDED BY THE USER.

The same reasoning can be applied to action, as illustrated in Figure 10. Problems can arise that are connected to: how the system *controls* the temporal action of the user, and how the user *affects* the temporal action of the system. The information system intentionally controls the user's temporal action by, for example, requiring some tasks to be executed in a specific order. In many cases this may be helpful. However, problems arise when the user's planning or actions are disturbed in unwanted ways. Examples from crisis management are: when the crisis manager constantly is interrupted by the cell phone during a crisis when he/she wants to focus on preparing the next meeting of the crisis management group, or when a crisis manager's work is delayed by slow response or update times of the system. Problems can also occur regarding how the user can affect the temporal action of the system. In a crisis management centre there may be an overview screen that shows available resources and ongoing events and response activities live. At some occasions there might be so much going on that the crisis manager does not have time to perceive everything at once. A way to address this could be to allow the crisis manager to "replay" an important sequence to check what actually happened. (Compare Shannon & Quigley (2010).) Even if such a feature would not be needed during the actual response, it could be of help when the crisis manager later is filling out a report documenting the response work. Affecting system action could further be as simple as scheduling an e-mail to be sent out at a later point in time. A county council changes their crisis management plans, and the information manager wants to send out a reminder to all personnel at the time when the plans come into force.
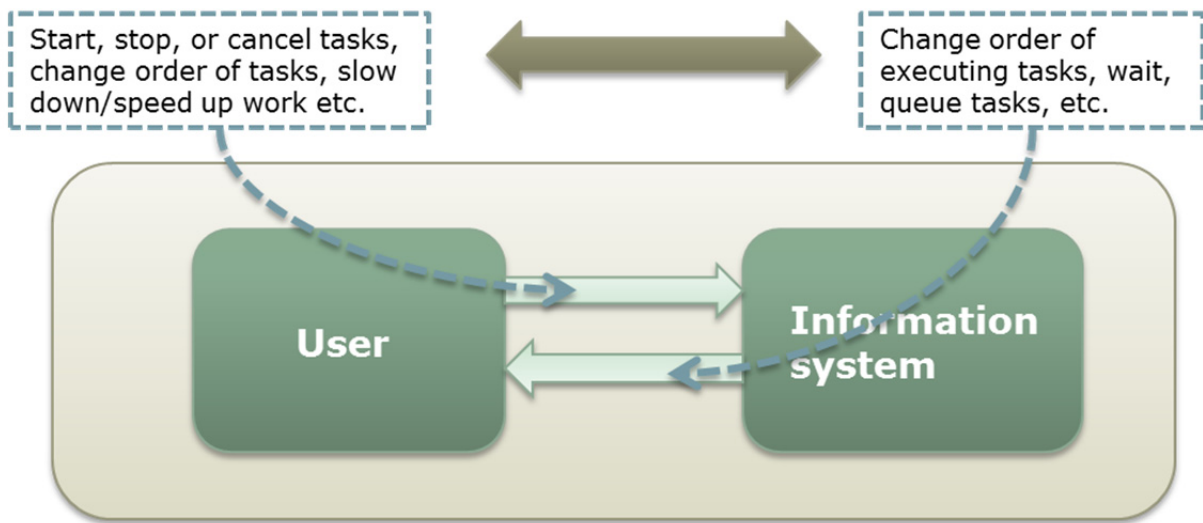
Temporal Action

FIGURE 10 – ALL ACTIONS OF THE USER AND THE INFORMATION SYSTM HAVE A TEMPORAL COMPONENT. THE TEMPORALITY IN THE ACTIONS OF THE USER AFFECTS THE INFORMATION SYSTEM, AND THE TEMPORALITY OF THE ACTIONS OF THE SYSTEM AFFECTS THE USER.

The discussion in this section is summarised in Table 4:

TABLE 4 - EXAMPLES DESCRIBING THE PARTS OF THE THOUGHT MODEL

Place to explore temporality	Explanation	Example
Information system **controlling** temporal action of user	How the information system influences the temporal action of user, for example, by causing the user to postpone tasks, speeding up an activity, or in other ways change planning and deadlines.	Response times. Systems requiring immediate attention from the user, causing the user to change plans or ongoing actions.
User **affecting** temporal action of information system	How the user influences the temporal action of the information system, for example, by setting the time for when the system should execute a task.	The user's possibility to influence dynamic information visualisation. Scheduling a task to be executed later by the system.
Information system **representing** temporal information of user	How the information system understands the information provided by the user, for example, whether the system can process the temporal information and perhaps use it to identify relationships.	Handling missing temporal information, such as not knowing specific time for when a storm is expected.
User **comprehending** temporal information of system	How the user understands the information provided by the information system, for example, the system only presenting time-stamps when the user is more interested in knowing the duration of events.	System presenting time for an event as "2011-02-19 12:45" while user is thinking about the event as taking place "last week". Choice of time-scale.

The *context* is an important element when exploring temporality. A user, an information system, and the interaction between them, are all influenced by other people, information systems, events, and other aspects of the context. All these aspects may in various ways include or affect temporality. Which aspects should be considered by the designers depends on the information system that is to be designed. In crisis management, a crisis manager is usually working in collaboration with people from both their own organisation and from other actors. The crisis manager is consequently affected by temporal aspects such as common deadlines, shift changes, colleagues' references to time when saying "the meeting starts in 15 minutes" or "the development of the storm is slower than last year". Accordingly, when using the thought model presented in this section in exploring temporal information or temporal action it is necessary to also have in mind how the concepts are influenced by the context around the user and system.

5.6 THE DESIGN PRINCIPLES, AND THOUGHT MODEL, REVISITED

The design principles for considering temporality in crisis management information system design have been presented in more detail in Section 5.4 and in appended papers II and III. To summarise, the design principles are the following:

1. Make temporal relationships between asynchronous activities salient;
2. Make information about past crises, and past crisis management events in ongoing crises, easily accessible;
3. Add create/last-modification time-stamps to information;
4. Indicate how events and activities may develop;
5. Support alternative temporal scaling;
6. Give support for emerging information sources;
7. Support the pace of the users' tasks and work; and
8. Allow for different users being responsible for the same tasks over time.

The design principles are based on the empirical data from the studies, and are also supported by findings from other research (see discussion in paper II and III). This supports that the design principles address actual design issues related to temporality. However, assessing how comprehensively the design principles cover possible design issues related to temporality is difficult. The studies have altogether included more than 25 participants, which means that a number of perspectives has been considered, but only seven of the 25 participants come from organisations other than municipalities and county councils. The design principles can be extended to cover additional problem areas if the findings were to be supplemented by research including other actors and crisis management systems from other countries.

The design principles are not based on one single definition of the time concept. In fact, one design principle can be viewed through the lens of different time concepts. As an example one can consider design principle 1 from the perspective of clock-based time and event-based time. In order to represent the relationship between asynchronous activities in an information system, commonly start/stop times and durations based on regular clock time are used. An activity, for example, the evacuation of a residential area after a flood, can be scheduled in an information system to start at 2011-06-23 15:00 using clock-based time. This representation is understood by the crisis managers using the information system. However, the crisis managers may also understand the evacuation as an event. They may think about it to start "before the water levels reach a specific limit", or "as soon as the neighbouring municipality have confirmed that there is temporary housing ready for the evacuated families". This means that they see the evacuation as an event in relation to other events.

The design principles can be divided into two major groups: one group comprising principles 1 to 6, which mainly concern what temporal information a crisis management information system should present, and how this information should be presented, and one group comprising principles 7 and 8 which address how the

information system should adjust to the temporality of the crisis response and management activities. The design principles help to bring two different perspectives together, since temporal information and temporal interaction normally are not discussed together in the literature. Exceptions are the works by Shannon et al., Lee, Wu and Franke et al. (Franke, 2011; Franke, Charoy, & Ulmer, 2011; Lee, 1999; Shannon & Quigley, 2010; Shannon et al., 2010; Wu, 2010).

The evaluation of the design principles described in paper III confirmed that the design principles: 1) can be used to identify design flaws in an interface, 2) can be a foundation for discussion about how temporality is presented in an interface, and 3) can inspire discussion about temporality in general. However, since the design principles are new, they have not yet been used in actual design. Further testing of the design principles must therefore be performed to validate their usefulness. The design principles focus specifically on temporality, and therefore they should be used in combination with other design principles and overall goals.

The design principles for temporality relate to the thought model as described in Figure 11 and Figure 12. Some of the design principles can belong to more than one section of the thought model since representation and comprehension are related, in the same way as controlling and affecting are related. For example, design principle 1 - making temporal relationships between asynchronous activities salient - concerns comprehension. It addresses the issue of how to visualise the temporal relationships stored in the system in order to make them clear to the user. However, design principle 1 could also be interpreted as belonging to representation, if the focus is on how to make data on crisis response activities and their relationships available to the information system.

Design principle 5 is a special case since "alternative temporal scaling" can refer to either temporal information or to temporal action. Alternative temporal scaling of information could mean changing the scale of a timeline represented by the system. Alternative temporal scaling of action could mean adjusting how frequently a crisis management information system should send updates to a crisis manager's mobile phone.
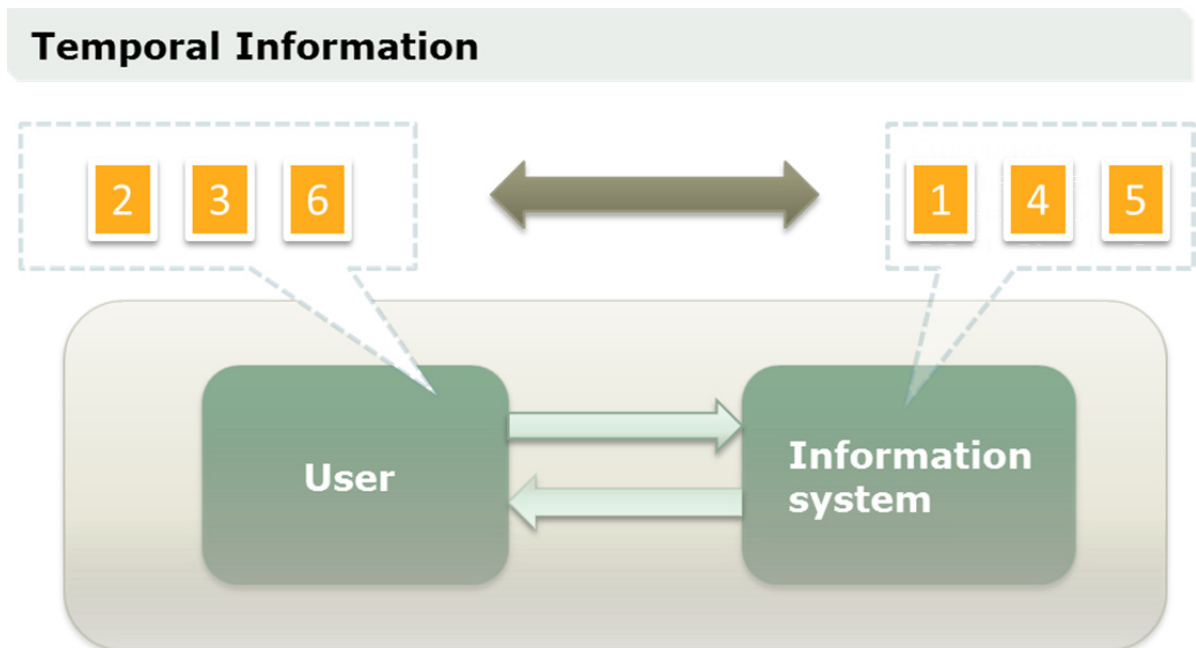

FIGURE 11 – THE DESIGN PRINCIPLES RELATION TO TEMPORAL INFORMATION.
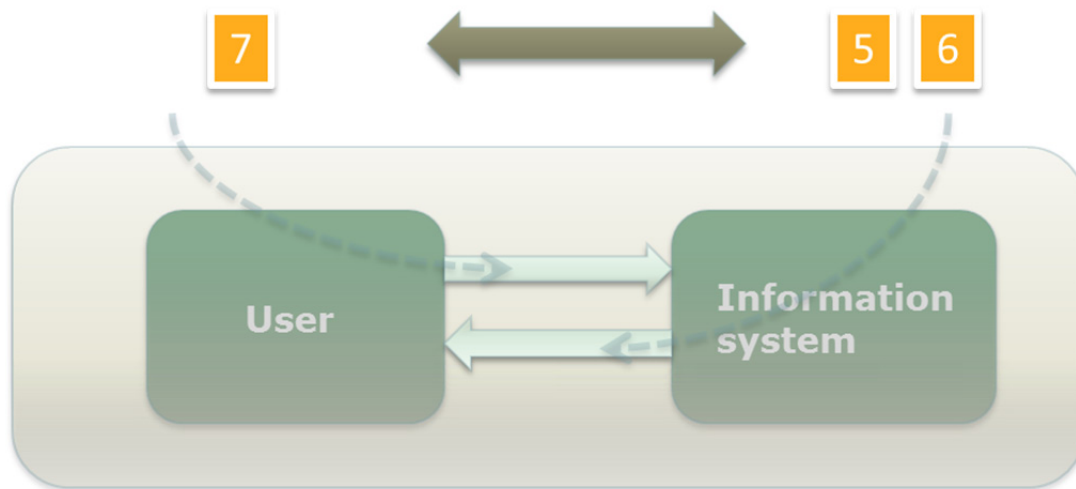
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Temporal Action

FIGURE 12 – THE DESIGN PRINCIPLES RELATION TO TEMPORAL ACTING.

The two concepts, temporal information and temporal action, are based on the outcome of the three studies described in the appended papers (see Section 5.5). The thought model could be extended depending on the specific needs of an interface design project. Instead of temporal information and action, the thought model could include temporal structures, as defined by Orlikowski and Yates, or investigate temporal rhythms. A design project interested exclusively in how to present time in an interface might focus only on the temporal information part of the thought model. Other projects, such as those developing machine interfaces, might focus exclusively on the temporal action part of the thought model as their primary aim is not information management. Nevertheless, temporal information and action are two rather generic categories that may be of some interest to most information system design projects.

Most of the literature in Chapter 3 and 1 addresses some specific aspect of temporality. The thought model complements the existing research by having a perspective that is more high-level and that opens up for exploration of several different views on temporality that can be of use when designing information systems for crisis management. For example, André et al (2007) and Li and Kraak (2008) focus on visualising temporal information, Dörner (1997) discusses how people perceive temporality from a cognitive perspective, and Franke (2011) addresses the management of temporal relationships between activities in crisis management systems. The thought model allows for exploration of issues from all these areas so that the discussion is not limited to only one kind of temporal matters. In the same way, the thought model allows for different time concepts (Adam, 1990; Hall, 1983; McTaggart, 1927; Orlikowski & Yates, 2002; Zerubavel, 1981) being used in the exploration of temporality.

There are two different concerns that make it necessary to be cautious in claiming that the thought model can be used in all information system design. First, every design situation is unique. This means that there may be different overall goals depending on if it is a crisis management information system or an accounting information system that is to be designed. As a consequence of the different goals, the designer may be interested in different aspects of temporality. Second, time is complex (as described in Section 3.2) and it is possible to use different perspectives when considering temporality. In this thesis it is argued that multiple perspectives are a valuable approach, because multiple perspectives can help highlighting different aspects of a design problem concerning temporality. However, it would be interesting for future research to attempt to specify when different perspectives are useful, and what methods a designer can chose in practice to make use of them.

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Transferability (Guba, 1981; Guba & Lincoln, 1982) is, just like crisis management information systems, time dependant. The design principles for temporality are for example only interesting as long as there exists crisis management, and as long as the crisis management is not organised too differently from present practice. The design principles are sensitive to changes over time, because crisis management does evolve and adjust to what risks are present in the society. Consider for example the impact 9/11 terror attacks and the hurricane Katrina has had on how crisis management is organised. It is reasonable to expect the design principles to be useful for quite some time, but a decision about whether they are up-to-date has to be made every time they are to be used in a design project. The thought model is more time-independent than the design principles. User and system are likely to be good starting points for a discussion even when information systems and design processes develop over time. Temporal information and temporal action are also concepts that are likely to stay stable over time. They would, for example, have been relevant to designers of information systems ten years ago.

Chapter 2 provides many reasons for why temporality is of importance in the design of crisis management information systems. It is, however, difficult to specify a direct connection between a focus on temporality and the overall success of information systems. It needs to be up to the specific designer to analyse what the benefits from a focus on temporality in a design problem can be. The work of this thesis has focused on crisis management information systems, and this implies that the outcome may be useful mainly to contexts with similar temporal issues. That is, useful to design for dynamic or time-critical work contexts.

6 CONCLUSIONS AND FUTURE WORK

The research question: *How should temporality be addressed in the design of information systems supporting response and management?* has no complete and unambiguous answer. However, two tools for addressing the question can be defined based on an analysis of the contributions of the appended papers. This chapter summarises and discusses the contributions, and presents possible directions for future work.

6.1 CONTRIBUTION AND IMPLICATIONS

The main outcome of the work in this thesis is:

- eight design principles for how temporality can be considered in the design of information systems for crisis management, and
- one thought model intended to support exploration of possible ways to address temporality in information system design.

The outcome is based on empirical data, supported by findings from other research. A side effect of the studies is also a better understanding of how information technology presently is used Swedish crisis management.

It has been shown in appended paper III that the design principles can be a support for finding design flaws in crisis management information systems, and also that they can trigger discussions on presentation of temporal information and on temporality in work practice. The advantage of the design principles is that they have an empirical foundation which implies that they address issues that can be found in actual crisis management information systems. They are also a complement to the design principles offered by Turoff, Chumer, Van de Walle, and Yao (2004) and (Endsley et al. (2003) as described more in detail in paper III. Since the design principles are new, they are considered tentative and require further validation and refinement, as discussed in paper III and in section 5.6. For example, by evaluating them against a wider range of crisis management information systems, and by testing them in a design context.

The main reason for developing the thought model presented in Section 5.5 is that time can influence most aspects of an interface design, and that there is little guidance in the literature that can be used to direct an exploration of how to address temporality in the design work. The thought model is not tied to one specific

definition of the concept of time, because, as has been argued in Chapter 3, different issues may be noted depending on what perspective is chosen on time. By not limiting the thought model to one specific time concept, the users of the thought model have the possibility to choose perspectives that are relevant for the specific design situation. To conclude, the advantages of the thought model as a description of temporality for design are:

1. The thought model is addressing temporality in design of crisis management information systems, but the concepts are general and applicable also in many other information system design contexts.
2. The thought model highlights the cyclic dependencies between user and system.
3. The thought model is extendable. It is possible to adapt the thought model by adding new focus areas in addition to *temporal action* and *temporal information*, and by removing areas that are not of interest to the specific design situation.

The design principles and the thought model cannot possibly address all interface design related issues encountered in crisis management information systems, but they are one way to approach temporality in design. They should be seen as a starting point supporting a more structured exploration of how temporality may influence a crisis management information system.

6.2 FUTURE WORK

The outcome answers the research question partly. Many interesting viewpoints remain to be investigated. The following list describes four possible directions for future work based on the outcome of this thesis:

1. ***Comparing result with systems from other countries.*** The outcome of the thesis is based on studies of crisis management and crisis management information systems in Sweden. It may be valuable to compare how the findings apply to other types of crisis management conditions. This could be done in different ways depending on resources. One possible set-up is to do a similar evaluation as was done in appended paper III, and to present the result for each system as a summary based on the thought model.
2. ***Observing real crisis or exercise.*** One way to validate the outcome of this thesis is to compare the outcome with actual crisis management. So far in the research project there has been very limited opportunity to follow actual crisis management in real time. Doing this may provide additional insights regarding the outcome that was not detected by the methods used to this date. The result from the observations could be presented based on the thought model of this thesis in order to explore if the thought model can provide a useful overview, and to note how the thought model can be improved in order to be a better tool for representing temporal aspects of crisis management information systems.
3. ***Developers' perspective on temporality.*** The work so far has focused on crisis managers' use of information systems. It may be fruitful to also investigate how information system designers view temporality. Do they consider temporality at all? If so, how have they considered temporality in previous design projects? What problems and possibilities do they see in addressing temporality in design work? Such an exploration may be difficult to conduct because time is a concept often taken for granted (see Section 3.2) and it might be necessary to define the concept at the beginning of any study involving designers. It is also useful to use very specific examples or cases that the designer can relate to in order to guide a discussion.
4. ***Confirming the usefulness of a temporal perspective in information system design.*** Chapter 2 provides many reasons for why temporality is of importance in the design of crisis management information systems. Further research is, however, needed in order to identify more specifically how a focus on temporality can contribute to the usefulness of information systems.

This list presents suggestions for how this work can be continued, but is not exhaustive. The thought model presented in this thesis approaches temporality in crisis management information systems (and information

systems in general) from a broad perspective. There are many opportunities for researchers interested in how to address temporality in the design of information technology to select a specific part of the thought model as foundation for further study. For example, by focusing on temporal information found in crisis management and how it should be processed and presented, or by focusing on the user and the different ways the user experiences and uses temporality in specific situations. The topic is complex, but this is also what makes it open for new and interesting findings.

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