Emergency Response Systems:
Concepts, features, evaluation and design

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CARER Rapport Nr.5

Publicerad av Linköping University Electronic Press

URL: www.ep.liu.se
E-post: ep@ep.liu.se

Detta verk skyddas enligt lagen om upphovsrätt (URL 1960:729).  
Upphovsrätten ägs av Bram och Verstergren, 2011.
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Introduction

In 2003, fire fighters in Hazelwood, Missouri were called to a traffic accident scene at Interstate 270. A man was stuck in his car and police were already on-site trying to assist him. When the fire department arrived, fire captain Wilson told the driver to position their vehicle in an adjoining lane, creating a closed-off work-space for the response effort. Immediately, a police officer tried to order the vehicle driver to move the fire engine. This order was revoked by Wilson, and in response to this, the police arrested the fire captain who was then removed from the scene (http://www.youtube.com/watch?v=DKzojYvXn20). Although this episode took place in the US, it serves to illustrate problems that appear to be ever-present in emergency response. Technology for emergency response has become very advanced, but efforts may still be inhibited by issues in interaction. How can collaboration between responding agencies be promoted at the incident site? How can they be assisted in situation assessment, planning, decision making and action? What technological and organizational support does this presuppose? These questions and many others will be explored in the present literature review.

Centre for Advanced Research in Emergency Response (CARER) is an interdisciplinary research environment jointly driven by Linköping University and the Swedish Civil Contingencies (MSB; Myndigheten för Samhällsskydd och Beredskap). This research environment carries out research and education around our society’s ability to respond to everyday accidents as well as to large-scale crises.

The aim of this study was to perform a review of the literature on emergency response systems (ERS) and related fields, with regard to central theories, terms and definitions, mainly focusing on everyday accidents. The literature review also aimed to identify research gaps and to reveal important emerging features to further develop CARER related research.

This review will start by exploring concepts from cognitive science and systems theory that underpin much of the current research on emergency response systems. A number of interaction-related concepts will be presented and subsequently used to structure the following chapters. The chapter on central ERS features begins with a section on system architectures, which is followed by a more extensive section dealing with emergency response coordination, going from issues to requirements and existing solutions. Next, issues connected to information and communication will be presented. This section expands on some of the themes visited previously and also covers the subject of information systems resilience. The next section also relates to the subject of resilience and deals with other ways of handling uncertainty in emergency response. The final section on ERS features explores training and learning within this context. The following two chapters present research on the modelling, evaluation and design of emergency management systems, covering both methods and some examples. This is followed by a chapter summing up areas of possible future research that have been identified. A final chapter provides a more general summary.
Background
This chapter starts by outlining a departure point which serves to frame the contents of later chapters. It describes the main areas of study in the domain of everyday incidents and suggests some similarities and differences between everyday incidents and disasters. The study of large-scale emergencies is important due to the lack of literature concerning everyday incidents. Because disaster management is such a rich source of information it cannot be disregarded in this context. The chapter continues to problematize and define the terms everyday accident and accident. Lastly, it provides a description of different phases in emergency management and a short brief on different roles in response, that is, ambulance and health care personnel, fire department, police, emergency dispatch, and lay responders acting at the incident scene.

The dominating picture of large-scale emergency management is one of uncertainty and complexity. Circumstances are constantly changing and operations are subject to strong time-pressures (Janssen, JinKyu, Bharosa & Cresswell, 2010; Nemeth, Wears, Patel, Rosen & Cook, 2011). Because of this, coordination is often very difficult to achieve (van de Walle & Turoff, 2008). In the words of Njâ and Rake (2009), crises are borderless threats that demand constant reinterpretation, often with the involvement of many stakeholders. When ambulance personnel, firemen and police officers must coordinate their activities toward shared goals, problems often arise around the collection and distribution of information (Bharosa, Janssen & Tan, 2011). This calls for well-designed emergency response systems (ERS), capable of supporting efficient and effective communication, coordination and action (Chen, Sharman, Rao & Upadhyaya, 2007).

Departure point
We as humans seem to have a low acceptance for large-scale accidents with large numbers of causalities. Conversely, accidents that occur every day and “only” take one or a few lives do not seem to bother us nearly as much. The Swedish National Board of Health and Welfare estimated that in 2010, 658 000 people in Sweden had visited an emergency health-care facility due to an injury (Socialstyrelsen, 2011a). Of these 658 000 injuries, 80% were classified as accidental events. The same year in Sweden, the number of deaths was 90 519, just above 5% of them (in total: 4659) on account of injuries (Socialstyrelsen, 2011b). For every event of death 22 persons were hospitalized (in total: 102 500), and an additional 119 treated in outpatient emergency care (in total: 555 700) (Socialstyrelsen, 2011a). There is no doubt that injuries and accidents are important health problems, and by adding time for convalescence and permanent disabilities due to an injury or an accident the problem increases further (Krug, Sharma & Lozano, 2000). Incidents occur every day and everywhere. Therefore, considerable gains may be achieved by studying them. More effective response at the incident site could result in both decreased societal costs and decreased mortality rates.

Studies concerning everyday incidents mainly focus on three areas; evaluation, risk reducing, and technical equipment. Studies evaluating everyday incidents mainly focus on one component of the incident, such as specific actors on the scene (e.g. Laskowski-Jones, 2002), stress levels of rescue workers (e.g. Gerber, Kellmann, Hartmann & Pühse, 2010; Kales, Tsismenakis, Zhang & Soteriades, 2009) or on single consequences such as post-trauma (e.g. Mayou, Ehlers & Hobbs, 2003; Robinaugh et al., 2011). The reduction of risk is often focused
on risk management, risk assessment and risk communication, often with the aim of developing incident system models (e.g. Leveson, Allen & Storey, 2002; Shrivastava, Sonpar & Pazzaglia, 2009). Some prevention studies focus on incidents and everyday hazards. However, many of them are executed in areas of the world such as Africa (e.g. Bull-Kamanga et al., 2003). Everyday hazards in these areas are different from those in Sweden, and they involve components, such as urban poverty, lack of infrastructure for providing water and the absence of human rights, that are not as extensive in the Swedish society. There is an extensive amount of studies on designing technical equipment to facilitate emergency response. However, most of the ones concerning everyday incidents focus on the use of mobile defibrillators in out-of-hospital care (e.g. Hallstrom et al., 2004; Weisfeldt et al., 2010).

The research domain of everyday incidents has many gaps. Very few studies deal with the everyday occurrence of incidents (Danielsson, Johansson & Eliasson, 2010; Demarin et al., 2010), even less with actual response. These scientific gaps are particularly noticeable when it comes to studies of lay persons, lay response, volunteers (Pelinka, Thierbach, Reuter & Mauritz, 2004; Stenberg, Blondin & Andersson Granberg, 2010; Venema, Groothoff & Bierens, 2010), the collaboration between different rescue organizations (Elmqvist, Brunt, Fridlund & Ekenberg, 2010), and the collaboration between lay responders and rescue organizations (Danielsson, Johansson & Eliasson, 2010). According to Krug, Sharma and Lozano (2000), one reason why injuries are overlooked in the scientific research is due to the fact that they are seen as random and accidental.

Another area lacking research is the study and definition of crises at the level between everyday incidents and disasters (Voss & Wagner, 2010). These are events that are too big to be addressed as everyday incidents, yet too small to be defined as disasters. In a Swedish context, the need for research on this level of incidents (so-called small disasters) may be more acute than studies of large-scale events.

Because research explicitly directed toward everyday emergency response is so sparse, much of the contents of this literature review will be gathered from the domain of large-scale crisis response. Quarentelli (2006) argues that there are both quantitative and qualitative differences between everyday incidents and disasters. However, even if there is – which we are not opposing, we argue that there may be lessons to learn from studies of the different phenomenon, and that these lessons can be beneficial to both traditions. Schraagen and van de Ven (2011) mention several issues often seen during large-scale crises. Temporary work groups typically lack common conceptions and may be unfamiliar of working together. This means that responsibilities are often unclear. Furthermore, private and public stakeholders must coordinate their activities, the public must be engaged and informed, system-handshake issues between agencies are common, information flow is often poor and actors may have a wide geographical distribution.

Although most current research within this field is directed toward these large-scale, multi-agency activities, some researchers make the claim that many of the features of massive emergency response can also be found in the handling of everyday incidents. For example, Nemeth, Wears, Patel, Rosen and Cook (2011) describe regular ambulatory healthcare in terms of flexibility and unpredictability. Operators are constantly engaged in fluid, dynamic cognitive activities and sharp-end workers often have to take the management initiative.
Everyday incidents also occur in complex environments, meaning that systems for frequent emergency response also must allow responders to tackle variability. Quarantelli (2006) highlights four organizational differences between the everyday incidents and disasters, one of which concerns the sudden nature of disasters. This forces rescue organizations, as well as other organizations, to „quickly relate to far more and unfamiliar converging entities“ (Quarantelli, 2006, p.1). It could be argued that lay responders experience this when they encounter an incident site.

A recent study on accident-site collaboration between Swedish agencies reveals many problems in coordination (Berlin & Carlström, 2011). Even for these seemingly routine activities, work is fraught with issues. Salaszyk and Lee (2006) argue that there is a direct relation between the efficiency and effectiveness of everyday incident response, such as the handling of traffic incidents, and response ability in the face of major emergencies. On a similar note, Nemeth et al. (2011) make the observation that crises are quite uncommon in the high-hazard industries normally associated with systems safety research. As a contrasting example, ambulatory healthcare deals with life-and-death situations on a daily basis. This means that everyday incident response can provide a wealth of data to inform the design of larger-scale emergency response systems. In relation to this, Landgren (2005) notes the comparatively low interest in small-scale emergencies, and makes the observation that such minor events can quickly develop into major crises if not treated correctly.

In risk accumulation it is important to conduct local based research to understand the processes and factors specific for different cities, counties etcetera (Bull-Kamanga et al., 2003). What may be defined as an everyday incident in one geographical area may be seen as a disaster in another. For example, in some areas of the world flooding occurs so often that they are seen as everyday incidents, while they in other areas of the world are seen as disasters. The continuous occurrence of these events makes communities adapt rather than take action or preventing them, or at least decrease their impact on the community (Bull-Kamanga et al., 2003). Voss and Wagner (2010) stress the importance of understanding the temporal and spatial framework of incidents. This is an important notion in research of the response phase of everyday incidents, which may lead to savings in lives, economy and time for individuals, organizations, communities and so on. This implies that there is a need for research in different areas and components in the response phase, and how they may differ between areas in Sweden, from big cities, to small cities, to rural areas. Kristiansen et al. (2010) points out the need for regional trauma systems that uses available resources due to all the rural areas in Scandinavia, something also noted by Andersson Granberg et al. (2010) and Stenberg, Blondin and Andersson Granberg (2010). Also, as noted by Andersson Granberg et al. (2010), Bull-Kamanga et al. (2003), McNeil and Quarantelli (2008), and Örtenwall (1999) incidents are different, and the geographical context where the incident occurs makes it necessary for the responder to use creativity and imagination. On the societal level this creativity may include other voluntary organizations already trained in rescue operations (see. Andersson Granberg et al., 2010; Stenberg, Blondin & Andersson Granberg, 2010).

Kapucu, Tolga and Demiroz (2010) describe emergency management as a process with specific demands. Different stakeholders must integrate their efforts and ensure collaboration. This means that trust and mutual understandings must exist between agencies, something that in turn demands a well-functioning system for communication and information
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sharing. Because of the dynamic nature of crisis events, a response system must also allow its operators to be flexible and creative when circumstances change. Research on the relation between people and their supporting technological systems has turned coordination and collaboration in emergency response into growing areas of scientific interest (Ödlund 2010). Consequently, these concepts still be thoroughly investigated in the present review.

**Definitions**

In the scientific literature, an *everyday accident* (as opposed to a disaster) is an incident that does not disrupt the structure or routines of society or rescue services (Danielsson, Johansson & Eliasson, 2010), can be managed at a local level, and where the creation of organizational convergence is low (Quarantelli, 1995, 2006). Everyday accidents are not particularly complex for the professional rescue services, and there is often well-established routines for handling them (Danielsson, Johansson & Eliasson, 2010; Demarin et al., 2010). According to Quarantelli (1995, 2006), one important distinction between an everyday accident and a disaster is that a disaster is socially created. Even though the number of lives lost in a disaster and in a certain type of everyday „accident” may be the same, everyday „accidents” are not seen as nearly as devastating as the disaster, except for the victims and their families. Bull-Kamanga et al. (2003) highlight that even though, in large cities, probably more than ten people are killed in traffic accidents every day and far more are injured, these events are not seen as disastrous due to the fact that they are several single events.

The term *accident* can create some confusion. Accidents are often seen as something unexpected that happens, such as a traffic accident, a fall, or a fire. However, what one person perceives as an accident may not be perceived as an accident by the next. Furthermore, what the professional rescue services may perceive as an accident may be perceived as a crisis or a disaster by a lay person. Additionally, cardiac arrests, domestic violence, suicide attempts etcetera, are all everyday incidents dealt with by the rescue services. However, these incidents are referred to as injuries rather than accidents. The World Health Organization (WHO) uses the term injuries (WHO, 2011). Injuries are divided into two categories, intentional and unintentional injuries, as part of the classification of diseases and injuries. Diseases are divided into communicable and non-communicable diseases. Intentional injuries are for example self-inflicted injuries, inter-personal violence and war-related injuries. Also belonging to the intentional category of injuries are traffic accidents, falls and drowning (Peden, McGee & Sharma, 2002; WHO, 2011). Non-communicable diseases include cardiovascular diseases, diabetes, some types of cancer and chronic respiratory diseases, and the communicable include maternal causes, conditions happening during the perinatal period and nutritional deficiencies (WHO, 2011). In this overview, to be able to include most of the everyday encounters for the Swedish rescue services and avoid the preconceived meaning of the term accident, we will use the more general term *everyday incident*. In this review, incidents included in the definition of everyday incidents are those that require assistance from more than one emergency organization, yet are not big enough to disturb the everyday work tasks of responding organizations or the societal structure, such as fires or traffic accidents. However, further research should aim at constructing sharper distinctions, both
contextual and typical, in order to shape more effective response systems for the everyday incidents.

In some cases, the use of central concepts in the literature caters for confusion. For example, the terms Emergency Management System and Emergency Response System are often used synonymously. CARER has decided to use the term response because its Swedish equivalent, in daily speech, covers all the phases of emergency management. Therefore, the term that will be most frequently used in this review is Emergency Response System (ERS), although its definition is a socio-technological system that enables preparation for, mitigation of, response to and recovery from emergencies. However, this report will focus on the response phase of emergency management, and the following section will expand on phase definitions.

**Phases of emergency management**

Emergency management is commonly divided into different phases (Chen, Sharman, Rao & Upadhyaya, 2011). Preparation means getting ready for imaginable future incidents, developing systems, managing resources, developing scenarios and plans and engaging in realistic training. Mitigation concerns actions taken to reduce the chances of an accident occurring (e.g. through risk assessment) or early attempts to make the consequences of an accident as small as possible. The Response phase covers actions carried out during the emergency, where joint efforts are made to save lives and minimize structural damage. Response may in turn be divided into sub-phases. How much time is needed for each of the phases Detection, Preparation, Response Travel and Clearance may affect outcomes (Salaszyk & Lee, 2006). Finally, the Recovery phase concerns activities to restore infrastructure, people and their property to normal. (Borges, Engelbrecht & Vivacqua, 2011). The present study will concentrate on the preparation and response phases given the delimitation of the assignment, but aspects of all other phases will also be touched upon, because they must all be integrated to some extent (van de Walle & Turoff, 2008). Van de Walle and Turoff emphasize that the preparation and mitigation phases must involve work to uncover vulnerabilities of an organization, a task in which the CARER project plays an important role. Even small advances may go a long way to improve response outcomes. For example, it has been shown that reducing accident response time by one minute may increase the number of lives saved by six per cent (White, Thompson, Turner, Dougherty & Schmidt, 2011).

**Roles in emergency response**

Response systems for both small and large crises are typically divided into first responders (medical personnel, fire-fighters and police) and different command structures. A Command Centre often holds the highest authority, making strategic decisions. Close to the incident site, incident commanders and other experts adapt response to the situation at hand, handling local resources and constraints, making decisions, evaluating risks and following up on operation progress (Borges, Engelbrecht & Vivacqua, 2011).

For an incident to become an accident site someone has to perceive and define the situation as an accident. This someone – the first responder – is often a lay first responder (Danielsson, Johansson & Eliasson, 2010). The terms „responsive” and „first responder” refer
to, in almost all scientific research, personnel in emergency and rescue organisations, that is, professionals. Thereby, first responders other than rescue service personnel, such as bystanders or voluntary organisations are excluded, also noted by Stenberg, Blondin and Andersson Granberg (2010). In this research overview we have divided the term in two. „Professional first responders“ are professionals belonging to a rescue team, while „lay first responders“ do not belong to a professional rescue service. In addition to these responders, we also add „bystanders“. These persons may be first at the incident site and thereby become „lay first responders“, but they may also be the third responder, fourth responder and so on, or just passive observers. The different roles in emergency response will be explained more thoroughly below.

**Ambulance and healthcare emergency personnel**

In Sweden, the county council governs the medical rescue organization (at incident sites most often ambulance personnel) (Berlín & Carlström, 2011). Everyday incidents are a large part of the workday for ambulance and healthcare personnel. Their mission at the incident site basically consists of medical treatment and transportation to the hospital (Berlin & Carlström, 2011). Another task the ambulance personnel face at the incident site is to establish local healthcare management, which in the case of a large-scale incident or several incidents at the same time communicates with and updates regional healthcare management to confirm that they are in fact dealing with a major incident (Rüter, Nilsson & Vikström, 2006).

**Fire department**

The fire department is at the organizational level mainly governed locally (Berlín & Carlström, 2011). At the site of the incident, their main function is to ensure safety for people, property and the environment (Berlin & Carlström, 2011; Danielsson, Johansson, & Eliasson, 2010), such as cutting victims out of cars or cleaning up gasoline leaks.

**Police**

In contrast to the other two professional rescue organizations, the police are governed nationally (Berlín & Carlström, 2011). For the police, these everyday incidents are only a small part of their workday (Danielsson, Johansson & Eliasson, 2010). At an incident site, they do not have as specific missions as the other two rescue organizations. The police’s main objective is to deal with „the rest“, which according to Berlin and Carlström (2011), and Danielsson, Johansson and Eliasson (2010) mainly consists of ensuring that the infrastructure at the site is working properly. This makes sure that the other two rescue organizations are able to carry out their missions without interruptions.

None of the above mentioned rescue organizations have the power to command the others at the incident site (Berlín & Carlström, 2011).

**Emergency dispatch – SOS Alarm**

Another important component, even though not physically present at the incident site, is the emergency dispatch centre, where the actual professional emergency response starts. Besides triggering the alarm, the emergency dispatch centre is also providing the responder at the incident site with basic life-support guidance. The emergency dispatch operators have to their help an alarm-guide with predetermined questions and instructions. The alarm-guide”s
function is to help in categorizing the incident and redirecting the information to the appropriate rescue organizations (Danielsson, Johansson & Eliasson, 2010). According to Danielsson, Johansson and Eliasson (2010) the emergency dispatch centre has to establish; 1) where the incident has occurred, 2) what type of help is needed, and 3) transfer the information to the responding rescue organizations and directing them to the location of the incident.

**Lay responders**

A fourth part often present at the incident site is the lay responder. Lay responder have been found to fill two important functions at the incident site; firstly as a source of information, and secondly as an extra pair of hands (Danielsson, Johansson & Eliasson, 2010). However, it is generally only when the rescue organizations are lacking personnel that the lay responders are seen as an asset.
Method

This literature review consists of a search for and a compilation of scientific research, gathered from journals and proceedings. Data gathered has given input both to the background and the results.

The search for literature started in Google Scholar, and from there fanned out into databases available at Linköping University Library. Google Scholar was used to get a wide range of results covering different areas and perspectives, by the use of certain keywords. These keywords were used in different combinations. The material was then structured and interpreted. One difficulty which needed to be addressed in the searching for articles was the inconsistency of concepts. The lack of general and distinct conceptual definitions over different perspectives may have had the result that some relevant studies have gone unnoticed.

The key words that were used included:

Bystander, cognition, cognitive, collaboration, communication, control, cooperation, coordination, decision-making, design, emergency, emergency responder, ERS, evaluation, everyday accident, first responder, information, interaction, lay responder, learning, modelling, pre-hospital, rescue team, response system, self-categorization, simulation, social identity, third party
Results
The preceding background has given some hints to challenges in crisis response that apply regardless of incident scale. The following chapters will present an overview of the corresponding research that attempts to explain and counter these challenges.

Systems and cognition
Response systems are complex architectures marked by heterogeneity and intertwined dependencies. In order to tackle this, many researches turn to the sciences concerned with the interaction between people and technology. Doing so presupposes an understanding of human cognition and its context-sensitive, distributed nature, and consequently, this will be investigated next.

Response systems involve dynamic configurations of people and technology. This means that if we want to understand how to construct efficient response systems, we must first have a sound understanding of how humans think and interact. Consequently, many researchers within the literature take off from cognitive models of human problem solving, collaboration and human-machine interaction when exploring their field. In this chapter, a brief background to the domain of cognitive science will be provided. Using cognition as an umbrella term, salient cognitive themes within the literature will be examined and later used to structure chapters on central response system features.

Models of cognition
Early models of cognition stemmed from logic and were centred on rational deduction. A rational agent, a Homo Economicus (Simon, 1955), was conceived to go about problem solving by iterating over all possible alternatives, making decisions based on probabilistic attribution. Because this development coincided with a veritable explosion in the field of computer science, thinking was modelled according to the functioning of a typical computer, comprising means of input and output, a long term store and functions for logical processing (Newell & Simon, 1972). This model of human cognition was later to be challenged by researchers stressing the importance of contextual factors. Human thinking, it was argued, is not a classically rational process taking place in isolation (Hutchins, 1995). Rather than a process in the mind it is better described a process in the wild (Hollan, Hutchins & Kirsh, 2000), affected by emotions, biases and culture, distributed over collaborators and objects. Cognitive artefacts, the term used for items that structure or take part in cognition, are inseparable from our reasoning. If we are to perform at our best, these artefacts must be carefully designed and hold the right affordances for cognitive support (Norman, 1993).

In relation to system safety, rationalist perspectives in early research on human professional activities produced a technological bias, where humans were perceived as a system”s weak link compared to highly reliable technological components (Hollnagel & Woods, 2005). Cognitive science came to challenge this assumption. While computer programs can only tackle complete and well-defined problems, humans are creative, flexible and quick in the face of dynamically changing environments. If we are to make the most of these talents, however, the tools we use must be designed to provide proper cognitive support. This implies that neither professional tasks nor technological systems for emergency response can be assessed or designed in isolation. Instead, it is the quality of interaction that will
determine system outcomes. In the words of Comfort (2007), understanding of human cognition transforms emergency management from a static set of procedures into a dynamic process dependent on our capacity to learn, innovate and adapt to changing conditions. This, in turn, depends on having the right information at the right time. Norros and Salo (2009) go even further, stating that humans should not only be conceived as creative agents in a system. Instead, people and technology should be considered as inseparable, engaged in a form of co-agency. If people and technology are to be described as a functional unity, methods are needed to model interaction. One strand of research that has had a deep impact, both on ERS research and the field of industrial safety in general, is the theory of Joint Cognitive Systems (JCS).

**Systems for interaction**

JCS theory stems from a situated, distributed model of human cognition and acknowledges the growing complexity of socio-technological systems (early noted by Perrow, 1984). Modern industrial systems are tightly coupled, meaning that disturbances in one end may spread and affect other, seemingly distant system constituents. Information technology has made it possible to provide operators with a wealth of data and coupling is widespread, but because of this, information overload may strike hard against our cognitive capacity (Adderley, Barnett, Smith, Westley & Wong, 2011; Woods & Branlat, 2010). Moreover, work analysis has often concentrated too much at the sharp end of operations, without acknowledging that actions performed by first-line actors (e.g. by first responders) are deeply affected by decisions made earlier, for example by system designers or persons higher up in the organizational hierarchy (Reason, 1990). This means that both systems analysis and systems design have to consider many different types of system interaction. A system can be argued to extend well beyond actors directly involved in the productive process, covering organizational layers, multiple organizations, public authorities and even the public itself (Hollnagel & Woods, 2005).

**Consequences for system design**

The field of Cognitive Systems Engineering (CSE) is occupied with the question of how to design systems in order to support distributed cognition. This perspective on systems design is often referred to in relation to ERS development (Norros & Salo, 2009) and will be used as a departure point for the present literature review. In the words of Norros and Salo, “intelligence” cannot be found in either individual humans or technological artefacts. Rather, it should be used to describe the appropriate functioning and adaptive capacity of a system, and design should be aimed at creating an “intelligent environment”. In accordance with their user-centred perspective, these researchers describe joint cognitive systems in terms of humans, technology and environment, where goal-driven processes are managed according to environmental constraints. Norros and Salo also argue that the principle for delimiting a system proposed by Hollnagel and Woods is unsatisfying, stating that it is too centred on the aims of the analyst. Instead, systems delimitation during analysis should be more closely related to activities and motives of people within the system. A JCS in operation, then, delimits itself according to its needs and demands in every specific situation.
Operators in a JCS do not only react to incoming feedback. They also create their own feedback by manipulating the process according to their current process understanding. Real world situations are fraught with disturbances stemming from both within and outside the system, and time is always scarce. This means that maintaining control is a continuous task, heavily dependent on the human contribution (Hollnagel & Woods, 2005). Coordination, that is to say, distribution and synchronization of work, is a central activity for a JCS. A long-lasting trend within many industrial domains has been to limit operator freedom through the use of barriers and automation. Hollnagel, Woods and Leveson (2006) instead argue that if operators are to cope with unexpected variability in the process, they must be able to respond with requisite variety. While this concept is fairly easy to apply to industrial settings, the same systemic feature could be argued for in an emergency response context.

Given the demands of real-world operations and the human contribution to crisis response, a system has to incorporate certain features. Disturbances may emerge in unexpected ways and it is impossible to foresee all possible future events (Hollnagel & Woods, 2005). The traditional high-risk industries are not the only ones to battle increasing complexity and uncertainty. Similar situations can be found in aviation, healthcare and civilian crisis management (Bergström, Dahlström, Henriqson & Dekker, 2010). From a systems perspective, resilience has come to denote a system’s ability to anticipate, monitor respond to and learn from adverse events (Hollnagel, Woods & Leveson, 2006), making it adaptable in the face of variability (Rankin, Dahlbäck & Lundberg, in press). Resilience is needed when a system goes beyond well-known territories covered by pre-formed plans and procedures (Nemeth, Wears, Patel, Rosen & Cook, 2011). Later chapters will show what general consequences this concept has for the design of response systems and put forward ideas around how this feature could be attained.

Cognition in the literature

What makes it likely that a system can anticipate and respond to adverse events? In the literature, a number of concepts are used to describe features that are relevant in this context, both individual and systemic. Cooper (2007) derives the activities of communication, coordination and control from cognition, stressing that cognition in many ways is a shared process. In the following sections, a number of terms central to this discussion will be brought up and related to the different stages of crisis response. These concepts will later be revisited when more hands-on features of response systems are explored.

Control

A system makes plans and takes action to approach certain goals, and in order to reach those goals, control is a prerequisite (Bergström, Dahlström, Henriqson & Dekker, 2010). Maintaining control is a shared process of adapting to context, a continuous management of known and unexpected variables. Comfort (2007) describes control in a disaster environment as „the capacity to focus on the critical tasks that will bring the incident to a nondestructive, nonescalating state”. In her view, control is not a matter of hierarchical authority, but rather a process of risk assessment, information integration, planning and monitoring. This reasoning approaches the Contextual Control Model (COCOM) proposed by Hollnagel & Woods (2005), where operators manipulate the process, creating their own feedback and maintaining
an ever-changing interpretation of the situation at hand. Woods and Branlat (2010) share similar conceptions, stressing the collaborative nature of control by connecting it to coordination and communication. Changing circumstances may force the roles of involved professionals to change, and over time, this may cause a shift of control within the system. In emergency response, just as in hospital environments, high uncertainties and rapidly evolving scenarios have the effect that control is rarely achieved (Nemeth et al., 2011). Working under time pressure and uncertainty, crisis managers often fail to communicate relevant information and to coordinate with other actors (Comfort, 2007). However, if operators are aware of the workload of other system constituents and attempt to anticipate upcoming demands, they may be able to create margins for manoeuvre. This is facilitated by modern information and communication technology. Johansson and Persson (2009) expand on this theme. They note that maintaining control is not simply a matter of maximizing the amount of available information, but to maximize understanding. Furthermore, trade-off situations will occur when system operators have to negotiate between competing demands (Hollnagel, 2009). A complex system held together by modern information technology contains numerous interdependencies that have to be understood if control is to be maintained. Some methods of tracking such interdependencies will be related in a later chapter.

**Situation Awareness**

One feature central for control is the understanding of the process at hand, its history and possible future states. Several concepts that approach this type of understanding exist in the literature, and *Situation Awareness* (SA) is one of the most prominent. Situation awareness is often described as essential for emergency management (Jungert, Hallberg & Hunstad, 2006; Lundberg & Asplund, 2011) and can be defined as "the knowledge of the state and physical location of people, objects and terrain within an area of interest" (Lass, Regli, Kaplan, Mitkus & Sim, 2008). SA is a form of vigilance heavily dependent on information management and communication. Moreover, it is connected to a system’s ability of predicting future outcomes. Because of this, a division of situation awareness has been proposed into *perception* (e.g. of problems), *comprehension* (of implications) and *prediction/projection* (of future events) (Adderley, Barnett, Smith, Westley & Wong, 2011; White, Thompson, Turner, Dougherty & Schmidt, 2011). Jungert et al. (2006) relate a division of awareness according to different operational features. In their terms, *Organizational Awareness* is the understanding of available resources and their possible use, *System Awareness* refers to knowledge about supportive technology and *Environmental Awareness* (including *Risk Awareness*) refers to knowledge about (possibly disruptive) contextual factors. The collaborative nature of situation awareness is stressed by Brons, de Greef and van der Keij (2010) who use the term *Activity Awareness* to cover what a person’s collaborators are doing, including what they are going to do in relation to shared goals. This mutual predictability is held forward as a key feature of emergency response, where multi-agency collaboration is common.

Some researchers choose to stress the distributed nature of understanding in terms of *Team Situation Awareness* (TSA) (De Koning, Huis in’t Veld, Kuijt-Evers, van Rijk & Theunissen, 2011) or *Shared Situation Awareness* (SSA) (Schaagen, Huis in’t Veld & de Koning, 2010), putting an emphasis on tools for information sharing, communicative skills and the importance of shared mental models. SSA concerns whether the members of a team
make the same interpretations of on-going events and whether they understand the needs of others, both of which hinge on their means and activities of communication (Comfort, 2007). This view is summed up by Salmon, Stanton, Jenkins and Walker (2011). They describe situation awareness as a feature distributed across human actors and the technology that they use, where cognitive artefacts have an important role in making information accessible. Comfort (2007), relating theories of Salmon, similarly states that team situation awareness can be thought of as a systemic property concerning the team as a unity, while individual and shared situation awareness concerns individual processes and overlaps between members. It should also be noted that the concept of shared situation awareness has received some criticism (Schraagen & van de Ven, 2011).

Several other concepts, seemingly related to situation awareness, exist in the literature. For example, Mindfulness is described as a capability for rich awareness of cues that may tell of potential accidents (van de Walle & Turoff, 2008), sometimes divided into individual and collective functions (Reason, 2008). Jensen (2009), drawing on concepts from Weick, describes Sensemaking as a continuous, adaptive process that human actors employ to guide decision making. This researcher stresses active functions of sensemaking such as goal setting and outcome assessment, and makes it clear that sensemaking should be understood as a way of exercising control (using a model very similar to Hollnagel’s COCOM). Jensen also mentions the collaborative nature of sensemaking as a process of coordination, and notes that participation (for example in goal setting) produces acceptance, commitment and thus, good performance. For a deeper explanation of the sensemaking concept in relation to crisis response, see Landgren (2005) who divides it into issues of Knowing where and Knowing what.

Van Santen, Jonker and Wijngaards (2009) focus on the concept of Shared Mental Models (2009), working in an emergency response context. This theory takes off from ideas about how humans form simplified cognitive models of reality, models that are used to predict events and behaviours in the world. Whether these models are shared between different actors is affected by feelings of shared ownership of responsibility, self-evaluation and self-correction, active sharing of information, mutual respect, experience in crisis management decision making and everyday contextual support for collaboration. In a breakdown of the concept similar to that of Jungert et al. (2006), shared mental models cover knowledge of shared technology, goals and requirements, team members characteristics (beliefs, skills, habits etc.) and common methods for dealing with problems.

Acknowledging the social dimension of collaboration, Lundberg and Asplund (2011) bring up the concept of Common Ground. Not only will shared constructs bring about better decision making and reduced workload in crisis situations. People who engage in social relations will also be able to interact more effectively, as opposed to people who have many conflicts. In other research, common ground is a communicative process, described in terms of constant negotiation. Goals and tasks are scrutinized and updated during the response to an event, ensuring predictability between actors involved (Bergström, Dahlström, Henriqson & Dekker, 2010). In response situations, this feature is thought to depend heavily on situational awareness (Comfort 2007). Common ground is joined with sensemaking (in the sense of comprehension) and coordination to form the more applied concept of Common Operational Picture (COP), by some researchers connected to shared situation awareness (e.g. Lass, Regli,
Kaplan, Mitkus & Sim, 2008). COP refers to the (physical) manifestation of collaborative, cognitive functions like situation awareness, sensemaking and common ground. It is a pool of information supporting the work and collaboration of emergency responders, contained in a database, describing past, present and anticipated future events (Norros, Colford, Hutton, Linnasuo, Grommes & Savioja, 2009). The construction of this COP is described by Comfort (2007) as vital for communication and coordination during multi-agency response, connecting it to common training, shared experiences among actors and professional interaction. In real-world operations involving many agencies, the quality of communication may be affected by inter-organizational tensions. In the worst case scenario agencies act competitively, and ideally, agencies engage in fully collaborative work (Yao, Turoff & Chumer, 2010).

**Decision making**

The shift in cognitive science, going from individualistic, rational models of intellectual functioning to context-sensitive and distributed cognition, was deeply associated to theories on decision making. Assessment of probabilities and utility are slow processes and real-world complexity makes for endless future possibilities (Comfort, 2007). Time is scarce, stakes are high and circumstances change. The world does not wait for the decision maker, who has to perform on demand (Worm, 2002). If humans do not base their decisions on probabilistic analysis, then how does the process work? An early answer to this question came from the study of fire-fighting command in real work situations, formulated into the theory of Recognition Primed Decision Making (RPD). Researcher observed that commanders, rather than trying to work up a complete set of possible actions, appeared to make decisions instinctively, by mapping certain situational features against their experience of prior events (Klein & Calderwood, 1991). This was conceptualized as a form of Naturalistic Decision Making (NDM), based on the discrepancy between an actor’s view of normal performance and changes in certain key indicators (Comfort, 2007). When a satisfying alternative is found, no time is lost pondering over other possibilities (Schraagen & van de Ven, 2011). In addition to fire-fighting, ambulatory healthcare and crisis response in general has been identified as activities likely to provoke this type of frugal decision making (Nemeth et al., 2011). Turoff, Hiltz, Plotnick and White (2008) connect NDM to expert knowledge. Drawing on the 1950’s research of Lindblom, experts are associated with extensive experience, giving them the ability to “muddle through” decision alternatives according to a few key values. They do not possess reasoning skills superior to those of novices, but are instead better at situation assessment (Njå & Rake, 2009). Kylesten and Nählinder (2011) have shown that for commanders to be successful they require well formulated goals. Furthermore, the current state must be observable, it must be possible to control the system, and the system must be represented in a truthful model (Kylesten & Nählinder, 2011).

As a contrast, Njå and Rake (2009) make the distinction between cognitive theories (such as RPD), where focus lies on the individual decision maker, and sociological theories (e.g. Contingent Decision Path) acknowledging the impact of organizational structure, hierarchies, role shifting, leadership and other types of social dynamics. The apparent narrow-mindedness of RPD, clinging to a course of action without proper reflection, could be seen as a threat to crisis mitigation. According to these researchers, a balance must be struck between individual and sociological factors in this context.
Experts adjust according to task demands, in order to relieve themselves from cognitive load (Worm, 2002). However, this is also a pattern seen in all persons who undergo stress, as described by the threat-rigidity hypothesis (Van de Walle & Turoff, 2008). Moreover, people solving problems together are susceptible to groupthink, where group consensus is prioritized over good decisions, and individual commanders must avoid many types of cognitive bias in decision making. On the other hand, commanders who have expertise and who trust in the performance of collaborators may enter a state of flow, where good performance is maintained despite a lack or overload of information. Van de Walle and Turoff (2008) argue that if response teams are to navigate this minefield, they must be trained for flexibility and creativity. On a similar note, Worm (2002) states that training of crisis responders has to be designed to facilitate natural decision making, something that according to Comfort (2007) is also increasingly common.

**Learning**

With previous comments on realistic training as a background, this section will relate some ideas from the literature on learning for emergency response. Van de Walle and Turoff (2008) argues for a type of training that emphasizes the active role of students, something that Hiltz, Ocker and Plotnick (2011) connect to constructivist theories on learning. Constructivist methods frame learning as something that a person does, rather than something a person is subjected to. When this methodology is used, students are encouraged to become active participants in learning activities, as a contrast to the passive role that these researchers associate with more traditional, so-called objectivist pedagogy. Moynihan (2009) seems to follow the same line of reasoning, describing learning as something that occurs when a person identifies and corrects a mismatch between expectations and outcomes. This definition stresses learning from experience, portraying the learner as an experimenter. Moynihan also brings up the social function of learning, in other words, learning as a way of sharing mental models within a group. *Groupware*, mutual understandings constructed during collaborative training, can later benefit communication and coordination in real-world operations.

Simulation is a common tool for learning within the high-risk industries, and increasingly so for the domain of emergency response. Working in artificial environments allows responders to gain familiarity with uncommon situations, and problems in collaboration may be uncovered. Using Piaget’s concept of *schemas*, internal representations of activities or transformations, Kylesten and Nählinger (2011) argue that schemas constructed when training in a micro world can later be transferred to other contexts. Among other things, this could mean that simulations have a value in teaching abstract thinking.

Taber (2008) draws on the research of Gee, highlighting a number of features in video games that could also be argued to hold for simulation environments. Firstly and perhaps obviously, virtual-world training allows people to learn in realistic environments without the negative consequences of real-world critical events. For this to be true, scenarios have to be modelled closely to realistic situations. Continuing, training in virtual environments keeps the learner active and promotes a questioning attitude, something that echoes the above statements of Moynihan. Persons administering training can also provide immediate feedback on a person’s progress, a key factor for efficient learning. Different ways of measuring learning can be used to adjust the level of difficulty, making sure that learners are

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appropriately challenged by their tasks and receive just the right amount of support. After training, learners may discuss their experiences and reflect on their performance. This is also a good occasion to connect training scenarios to real-world experiences. Taber (2008) notes some features in simulation environments that are particularly important to maximize impact. Just as in the real world, virtual learning environments should be open-ended and freed from pre-defined outcomes, so that learners can explore the consequences of diverse combinations of decisions and actions. This may encourage creativity and compensate for the fact that procedures and rules cannot cover all possible states and events in a crisis situation. Moreover, designers of virtual training environments should provide a good match between the resources available for learners and those that would be found during a real crisis. This could mean everything from the design of technological artefacts to team configurations, cross-team interaction, between-agency interaction, contacts with outside resources and so on.

**Response system features**

Cognitive systems theory gives that a well-designed system should support shared cognition. This concept can be split into a number of sub-requirements. If people and technology are to function as a systemic unity, structures and tools must support *coordination*. A system’s ability to coordinate work depends on its *architecture*. Furthermore, it rests on efficient and effective structures and tools for *communication* and *information handling*, including a well-functioning information system. Because actual incidents are often associated with dire consequences and there may be limited chances for mid-event learning, structures for *training* and *learning* are key features of an ERS. Finally, as noted several times in previous chapters, emergency responders are typically heavily affected by environmental and contextual circumstances. This means that we must try to understand what allows people to *handle uncertainty* and adapt to circumstances. The above concepts, in addition to related research strands within the literature, will be used to structure the following chapter on response system features.

Consequently, going from the general to the specific, research and examples of social and technological implementations will be reviewed under the headings *System Architecture, Coordination, Communication, Information systems, Handling uncertainty* and *Training and learning*.

**System architecture**

The background chapter described the consequences of applying a JCS perspective to the study and design of response systems. Humans are the ones capable of handling the dynamics of real-world conditions and our cognition depends heavily on information, cognitive artefacts and collaboration. This means that response systems must be designed to support coordination and communication. Perhaps the most fundamental question, then, is how to configure the organizational architecture of such a system.

In the past, organizations have commonly been structured according to a hierarchy (Schaagen, Huis in ’t Veld & De Koning, 2010) where an upper control unit makes plans, decisions and distributes information. This is still true for information architectures in many public safety organizations (Bharosa, Janssen & Tan, 2011). However, Schaagen et al. further argue that time pressure and multi-agency involvement often means that central
coordination is difficult to practice. A dominant type of leadership can make it harder to voice objections within the organization. It may also hamper collaboration and instances further down in the hierarchy may become more inactive (Berlin & Carlström 2011). When unexpected situations arise at the sharp end of operations, centralized authority may find it very difficult to grasp how the situation is developing. These conceptions are supported by analyses of large-scale crisis response. For example, Comfort (2007) describes the response to hurricane Katrina as a clear demonstration of the failure of hierarchical control. Although the US national emergency management system was reorganized following the events of September 11, 2001, it still adhered to a traditional model of command and control. According to Comfort, divides between key agencies inhibited the flow of information, which led to problems in communicating the detection of the emerging disaster. This meant that actions of response became severely delayed.

Organizations must be adaptable if they are to counter uncertainty (Schaagen & van de Ven, 2011), which seems to call for more flexible organizational structures. Turoff, Hiltz, Plotnick and White (2008) make a case for delegation of authority. When flexibility is required, decision authority has to be transferred to those who are close enough to event, because they are the only ones who can know what particular constraints apply to the situation at hand. This is an argument in favour of localized expertise and group collaboration in decision making. But more comprehensive concepts for reorganization exist in the literature. Woods and Branlat (2010) use the term polycentric control to describe organizations with multiple, interdependent centres, where each node has partial autonomy and authority. These centres may be responsible for different subgoals, and the model is claimed to be especially suitable for disaster response and military operations. In this type of organizational structure, upper management should mainly be occupied with conducting oversight and seeking out additional resources (Turoff, Hiltz, Plotnick & White, 2008). Schraagen, Huis in ,t Veld and de Koning (2010) refer to a similar concept, using the term network structure. A team organized as a network allows for free exchange of information. Decisions are made in a collaborative manner and its members work together toward a common goal. Previous research cited by Schraagen et al. has showed that teams structured as networks are faster, share more information and are more accurate in their actions. Although experiments showed no overall effect on the quality of decisions, the handling of particularly difficult missions seemed to benefit from sharing of specialist knowledge.

Network structures have also been hypothesized for entire organizations. Because of their flexible and diverse nature, such architectures could provide resilience in human relief operations (Kruke & Olsen, 2005). Decentralized, team based structures like these are often referred to as Network Centric Organizations (NCO). The principal feature is a free flow of information between units and even organizations (De Koning, Huis in’t Veld, Kuijt-Evers, van Rijk & Theunissen, 2011), providing actors at all levels with the proper situation awareness to make decisions and fulfil their assignments (Schraagen & van de Ven, 2011). As noted by Bharosa, Janssen and Tan (2011), this means fulfilling “the four rights” of supplying the right information, at the right time, in the right form, to the right person. By levelling the organization, focus is placed on the quality of interaction and coordination, and on the shared understanding of the current mission. This may empower individuals to adapt when circumstances change (Bharosa, Janssen & Tan, 2011), and consequently, the organization
will become more resilient. One explanation of the benefits of NCOs is provided by the US Department of Defence, referred to by Janssen, JinKyu, Bharosa and Cresswell (2010). Structuring a force like a network improves information sharing. This, in turn, enhances the quality of information and creates shared situation awareness. Shared situation awareness makes it possible for actors to synchronize their activities and speeds up command. As a result, mission effectiveness should be dramatically increased.

Some researchers are critical to the alleged benefits of network centric organizations. While networks may provide a more effective exchange of information, something that in turn may favour learning, Moynihan (2009) means that they may also lack the groupware of hierarchical organizations. Because norms and understandings are not shared between the different parts of the network, learning could be inhibited. Ödlund (2010) notes that the quest for power balance within an NCO may lead to unclear authority and responsibility. This could have negative consequences for emergency response effectiveness and raise questions around accountability. In a network the number of connections increases dramatically when the organization grows, possibly making it hard to overlook. Bharosa, Janssen and Tan (2011) mean that while network centric architectures have proven effective for military operations, applying NCO architectures to emergency management could have negative consequences. Allowing a free flow of information could result in information overload for relief workers. As opposed to actors in a hierarchy, members of a network may find it hard to decide who needs what information, at what time and in what form. A free flow of information could also give commanders a false impression of situation awareness and give rise to excessive improvisation closer to the sharp end.

Giving some nuance to this conflict, Ödlund (2010) suggests that both models have their benefits. While hierarchies may favour efficient command through mandate clarity and straightforward instructions, networks may favour cooperation through compromise, discussions and frequent meetings. Some researchers (e.g. Windischer, Grote, Mathier, Meunier Martins & Glardon, 2009) suggest that the degree of uncertainty in operations could be used to determine the suitable organizational architecture. Systems facing a high degree of uncertainty will likely benefit from distributed authority, while centralized authority may be suitable for operations of low uncertainty. Similar conclusions have been drawn from experiments on different team structures. Hierarchical teams perform better than network teams when demands are low and the environment is stable and predictable. Network teams, on the other hand, excel when high demands are combined with dynamic and complex environments (Schraagen, Huis in „t Veld, & de Koning, 2010). Kapucu, Tolga and Demiroz (2010) point to research showing that bureaucratic management can be powerful, and that central command structures have proven effective for coordinating networks of diverse groups of actors. They suggest that it may be possible to strike an effective balance between the two, using a combination of hierarchical and network features. Ultimately, however, whether this would be possible within an ERS context remains an open question (Janssen, JinKyu, Bharosa & Cresswell, 2010).

**Coordination**

Coordination begins with an assumption of differences and a risk of overlaps, redundancy, and separation between actors during an operation (Kapucu, Tolga & Demiroz,
2010). It refers to how organizations, teams and individuals within teams time and integrate their actions (Schraagen & van de Ven, 2011), for example around resource allocation, in order to achieve a shared goal (Comfort, 2007). In order to carry out coordination successfully, actors must obtain a shared understanding of the task at hand (Jensen, 2009). Problems in coordination have been identified as a central issue for emergency management (Woltjer, Lindgren & Smith, 2006). During crisis handling, actors from different organizations have to work together, despite differences in education, expertise and technological support systems (Jungert, Hallberg & Hunstad, 2006). As this chapter will show, there are many ideas around how to achieve coordination in emergency response.

During operations, coordination depends on technology, procedures and plans, leadership and cultural norms (Grote, Weichbrodt, Günter, Zala-Mezö & Künzle, 2009). Schraagen and van de Ven (2011) make a distinction between explicit and implicit coordination, where the former denotes transfer of resources to explicit requests, and the latter has to do with a more tacit form of coordination stemming from shared experiences. Team members engaged in implicit coordination offer each other assistance voluntarily, in a very effective manner. Berlin and Carlström (2011) distinguish between different forms of coordination, sorting them into a hierarchy of coordination quality. Sequential coordination is the basic turn-taking at the accident site. When parallel coordination is employed, tasks are strictly distributed and performed side-by-side. Finally, synchronous coordination denotes a smooth, seamless exchange of tasks. Effective crews have been observed to engage in less complex interaction, using simpler action and less communication between operators (Bergström, Dahlström, Henriqson & Dekker, 2010). This last type of coordination constitutes an ideal for multi-agency operations, but it is typically hard to achieve. A similar hierarchy is presented by Turoff, Hiltz, Plotnick and White (2008), focusing more on between-team coordination. In their model, team communication can span from competitive (where actors have little trust in information from other teams), informative (honest sharing of information about each team’s activities) through coordination (mutual scheduling of separate tasks) and cooperation (mutual agreement on division of tasks), to true collaboration (mutual agreement to work together on shared tasks).

**General challenges in emergency response coordination**

In Norway and Sweden, first responders often have to take initial command before the arrival of a nominated incident commander (Njå & Rake, 2009). This means that within-team coordination is vital. However, equally great challenges may exist in multi-agency collaboration. Berlin and Carlström (2011) studied on-site collaboration between police, ambulance personnel and fire-fighters. Although the Swedish law states that organizations involved in emergency response should collaborate, this study shows that actual collaboration has many issues. Previous research has revealed competitive attitudes between agencies. It has also been shown that when operators are pressurized, they revert to within-agency established behaviours. In the Swedish context, new information technologies such as mobile phones, text messaging and separate communication systems have made it more difficult to share information between agencies. Furthermore, no structures exist for commanders to gather and collaborate at the accident scene. In this study, coordination between agencies was perceived as a daunting task by interviewees. Personnel from professional rescue
organizations want to collaborate in an „excellent form“ (i.e. synchronous), yet, collaboration is avoided in practice. This form of collaboration at incident sites was found to be avoided due to absence of incentives and because of the conception that collaboration may create uncertainties. Each organization focused on their own tasks, and when they were done they returned home. Also, instead of lending another organization an extra pair of hands, personnel typically became passive when they had finished their own specific work tasks.

Apart from issues in information sharing and uncertainty about the activities of others, Berlin and Carlström (2011) also identify cultural divides that prevent efficient goal-sharing. McMaster and Baber (2011) point out that similar issues have been seen before. Different agencies often have limited understanding of each other’s activities. Besides poorly integrated information systems and lacking structures for coordination, between-agency cooperation is often held back by competitive behaviours and lack of trust. Such divides between organizations may cause operators to attribute all problems to other agencies, due to in-group/out-group bias (Windisher, Grote, Mathier, Meunier, Martins & Glardon, 2009). Ödlund (2010) gives another example, describing shortcomings in the Swedish response to the 2004 Asian tsunami disaster. “Cultural distance” and “cultural barriers”, differing norms and lack of understanding and trust, led to problems in inter-agency collaboration. Although agencies may collaborate at higher levels, interaction is still often lacking between teams working in the field. This will strongly affect outcomes.

In a study on teamwork amongst professional pre-hospital actors and teamwork and relations with non-professional groups, Pereira and Lima (2009) found that pre-hospital care has its foundation in teamwork. Also, they emphasize the need for professionals to rise above the historical hierarchy existing within health organizations, keeping them from effective teamwork. In addition, Forland, Zakariassen and Hunskår (2009) studied the relations in pre-hospital care between ambulance personnel and doctors and nurses in the out-of-hours service. 78 % of the ambulance personnel perceived their own group as the most competent at the incident site. They also reported a feeling of not being acknowledged by the doctors. This experience of feeling unacknowledged may add to already exiting boundaries, and may affect views on different group legitimacies at the incident site, thereby also affecting the collaboration between them. Further, only 19 % of the ambulance personnel perceived that others appreciated their knowledge and competence in the multidisciplinary teams (Forland, Zakariassen & Hunskår, 2009). Also, the ambulance personnel experienced the collaboration with the nurses and doctors in the out-of-hours services as the most problematic when compared with other organizations involved in the pre-hospital care. This may be a result of the collective self-image of the group, which according to Berlin and Carlström (2011) makes it hard to step aside and let someone else do „their“ job, further aggravating the possibilities of collaboration. This difficulty in collaborating does not only exist at the incident site. McNeil and Quarentelli (2008) notes that there are strains in the everyday life between police, fire service, emergency services, public groups and private groups that affects the ability to collaborate in a good way during disasters. One may assume that these strains also affect the ability to collaborate in everyday incidents.

While collaboration is a very common theme in ERS research, some opposing voices exist. Danielsson, Johansson and Eliasson (2010) argue that collaboration is often seen as more important than it really is. They state that collaborative behaviour is not always
important and not always significant to everyone. This conclusion is drawn from their view
that in less complex incidents, it may be more effective to let the various rescue organizations
work alongside with their specific tasks, rather than jointly and collaboratively. Elmqvist et al.
(2010) found that different rescue organizations at an incident site had a great confidence in
each other, and that there was no apparent rivalry between them. The rescue organization that
collaborates the most with other professional rescue organizations at incident sites was the
police (Danielsson, Johansson & Eliasson, 2010).

In relation to the above section on intra- and inter-team difficulties, Militello, Patterson, Bowman and Wears (2007) uncovered issues related to differing experience levels, testing Emergency Operations Centre personnel in simulated disaster scenarios. Some actors had poor knowledge about emergency response tools and procedures, as well as of the roles and functions of other EOC actors. There were also problems related to supporting technology. Information channels were quickly overloaded and the updating of shared information resources, in themselves unfamiliar to some participants, was abandoned due to high workload. The resulting lack of information flow had the result that both information and workload became unevenly distributed. In the event of a major crisis it is unlikely that all those that need to cooperate will have trained together, and that events are fully covered by imagined scenarios (Tuorff, Hiltz, Plotnick & White, 2008). For everyday scenarios, however, there could be lessons to learn from this.

**Coordination and social identity**

The social context of an incident site often includes several different professional
groups, as well as bystanders. This makes it relevant to examine inter-group processes during
response to everyday incidents. Doing so may help to increase well-functioning collaboration
and to make the response system as effective as possible.

According to the social identity theory (SIT) our self-image is connected with various
social categories, and we perceive others from the perspective of our own social category. The
self-categorization theory (SCT) adds inter-group processes, the perception of one”s own
group and other groups (Turner, 1982). As an extension of the SIT and SCT, the elaborated
social identity model of crowd behaviour (ESIM) was developed (ESIM; Drury & Reicher,
2000, 2005; Reicher, 1996; Stott & Reicher, 1998). ESIM can be seen as the part of SCT that
is concerned with crowd behaviour, and views changing and evolving social identities within
a group as a function of intergroup dynamics. ESIM differentiates between physical and
psychological crowds (e.g. Drury, Cocking & Reicher, 2009). The psychological crowd
emerges through members perceiving that there is an opposing out-group acting against them,
a shared threat, which in turn makes them perceive themselves as one. In a specific social
context, social categories (such as emergency responders) are created through the social
comparison of intergroup relations. This may in turn lead to changes in those intergroup
relations (Drury, Stott & Farside, 2003; Stott & Reicher, 1998; Stott et al., 2007; Stott, Adang,
Livingstone, & Schreiber, 2008). Also, changes in social identity that are made salient may
lead to changes in the behaviours and ideas of the group, and also the type of collective action
(Stott, et al., 2008).

The relevance of these theories in everyday incident research is that; 1) a shared social
identity may facilitate collaboration at the incident site – thereby contributing to a more
effective emergency response, 2) since the social context at the incident site is constituted by
different groups, intergroup processes needs to be acknowledged, and 3) even though not as
strong as with disasters and mass emergencies, the incident may be perceived as a shared
threat amongst the lay responders, emerging a shared relationship, a shared social identity that
influences our norms and behaviours, and the collective action.

Based on SCT, Levine, Cassidy, Brazier and Reicher (2002) studied social category
relations and individuals present at a violent incident. They conclude that in developing
strategies for intervening behaviour, self-categorization plays a key role. In helping after an
emergency, Levine and Thompson (2004) found that relations based on social categories were
of greater importance than geographical proximity or emotional reactions. Thus, the
membership of a social category is an important factor behind intervening behaviour, and
amongst bystanders, a shared social identity may promote intervention (Levine & Crowther,
2008). When an identity shifts, the feeling of responsibility may also shift (Levine &
Thompson, 2004), and this shift in the social context elicits a shift in the self-categorization
amongst individuals (Levine et al., 2002). Also, when responding to incidents, behavioural
norms of a salient social identity and the intergroup context influence the way in which group-
members act (Stott & Reicher, 1998). Levine et al. (2002) found that bystanders were more
influenced to intervene, or not to intervene, by the actions of perceived in-group members
than by the actions of perceived out-group members. Also, if the victim was perceived as an
in-group member, bystanders were more willing to intervene. As noted by Levine et al.
(2002), bystander behaviour is influenced by social category relations between bystanders, as
well as relations between bystanders and victims. Furthermore, those two relations may stand
in relation to each other.

Our perception of meaning is created through interaction with others (Danielsson,
Johansson & Eliasson, 2010; Demarin et al., 2010), and an organization is based on
preconditions of who we are and what we do, preconditions based on earlier encounters and
experiences (Berlin & Carlström, 2011), which affects our social category relations.

According to Ödlund (2010), social identity may hinder collaboration since it divides
people into them and us. She argues that what hinders collaboration in this respect is due to
„faulty expectations and prejudice” (p.102). Although this may be true, collaboration may
benefit if the social identity made salient is, for example, „rescue workers” instead of several
minor social identities such as „ambulance personnel” and „police”. There is much to gain by
sharing a social identity. Research in collective behaviour and social identity have, amongst
other things, found that large numbers of people in a group may lead to greater experiences of
group-efficacy (Reicher, Levine & Gordijn, 1998) and increase collective behaviour (Drury &
Stott, 2000). Also, a shared social identity will make us appreciate others more while in
crowds (Drury & Stott, 2011).

Collaborative training that involves all emergency rescue organizations may transform
the social identity at an accident site from „us the ambulance personnel” to „us the emergency
responders”, including all on-site rescue services. However, organizations at everyday
incidents and social identity are areas where further scientific studies are needed.
Emerging requirements

A comprehensive account of possible ways to improve coordination is provided by Chen, Sharman, Rao and Upadhyaya (2011). Prior to a crisis, organizations must join in the creation of procedures, support systems, training and exercises, using knowledge about real-world requirements for information and information dissemination (Salmon, Stanton, Jenkins & Walker, 2011). This will produce shared visions and inter-organizational situation awareness, something that has been demonstrated to be vital for multi-agency coordination during an actual emergency (McMaster & Baber, 2011). Actors from different organizations working together will form social relations that will improve decision making in sharp situations. As noted by Salmon et al. (2011), pre-crisis joint training may also serve to make roles and responsibilities clear, defining the division and flow of authority and leadership.

Some researchers have suggested that the most important part of preparing for crises is not the plans made, but rather the process of planning (e.g. Eriksson, 2009). When organizations join in the making of plans they will form structures and relations which will make it easier to coordinate efforts during an actual emergency. This could also be taken to mean that plans have to be combined with proper joint training initiatives in order to maximize their potential. The same theme is visited by Windischer, Grote, Mathier, Meuiner, Martins and Glardon (2009) under the heading Collaborative Planning. To these researchers, a unified planning process may compensate for uncertainty in a complex environment. Strict plans and demands for absolute compliance may cause problems when unexpected situations arise. If local actors and teams are instead allowed to participate in the planning process and contribute with their sharp-end contextual knowledge, then such situations may be avoided. An important feature for coordination of efforts will then be to share revisions of plans among participating organizations and stakeholders. In the study by Windischer et al., a high quality of collaborative planning produced an improved logistical performance. In the light of everyday emergency operations where every lost minute may have serious effects on outcomes, this makes a strong case for working with inter-organizational structures for coordination.

When an emergency occurs, commanders from different organizations should form a joint command centre which can oversee the on-going process of coordination, creating a global picture of the situation and providing resources for field operators. Here, efficient processes must exist to gather, integrate and disseminate information. This will help to form a shared understanding of the situation. Both command centre and work teams need artefacts for information handling that are easy to learn, as well as proper support for on-site use (Militello, Patterson, Bowman & Wears, 2007).

To support coordination, efficient communications must also be established. Actors from different agencies should engage in face-to-face dialogue and try to promote trust between organizations. In US studies, increased frequencies of interaction and information sharing have been connected to increased levels of effectiveness in emergency operations (Kapucu, Tolga & Demiroz, 2010). Furthermore, control room research has shown that coordination depends on informal verbal communication, gestures, gazes and use of technology (Latiers & Jacques, 2009). This may have consequences for the design of emergency command centres, where design could encourage good communicative practices (Militello, Patterson, Bowman & Wears, 2007). Furthermore, communication systems must
not rely on vulnerable infrastructure and should allow users to overhear communications. As noted by Janssen, JinKyu, Bharosa and Cresswell (2010), it is common that information systems are designed according to probable scenarios, with a strict focus on intra-organizational processes. It is equally important to evaluate systems with respect to inter-organizational coordination and flexibility in situations that are not covered by scenarios.

Although information sharing has emerged as a central prerequisite of coordination, simply sharing all information with everybody may have negative consequences (Bergström, Dahlström, Henriçon & Dekker, 2010), an issue which will be revisited later. Bergström et al. differentiate between forms of team interaction. In experiments, teams that attempted to share all information and make consensus decisions became overloaded when work became too demanding. On the other hand, for a team implementing a strict command structure, the team leader became overloaded during high-intensity events, and coordination suffered accordingly. A third variety saw teams that tried to implement a strict division between work roles. Here, predictability suffered, because team members lacked information about the activities of others. Finally, teams working with clearly defined roles, but where members communicated about their respective responsibilities, displayed the best performance. The leaders of these teams were not occupied with decision making. Rather, they supported the coordination process itself, updating members on changes in goals, needs for resources and changes in work roles. Bergström et al. note that there is a need for research on processes of inter-team and inter-organization coordination, where the fundamentals of JCS research could be used as a framework for analysis. This is echoed by Janssen, JinKyu, Bharosa and Cresswell (2010), who mention the need for flexible coordination mechanisms for inter-organizational work. In their view, one possible route could be research on network centric operations. Furthermore, coordination must not only be a matter of top-level interaction, but should be an active process at all organizational levels.

Perhaps associated with the seamless nature of synchronous coordination is the process of role allocation. In work teams, too little specialization has been observed to result in duplication of work. Extreme specialization, on the other hand, may result in lack of overview for team members (Schaagen, Huis in „t Veld & de Koning, 2010). Van de Walle and Turoff (2008) suggest that this must be a question of adaptability. In order to meet situational needs, team members should be able to take on different work roles, something that is also suggested by Rankin, Dahlbäck and Lundberg (in press). This presupposes that roles are clearly defined and that these definitions are available in an information system, describing tasks, responsibilities and information needs. Van de Walle and Turoff (2008) suggest a framework for role allocations within a team. These should cover functions for making valid requests for resources, making situational observations and gathering information, allocating resources, monitoring possible interferences for allocations, maintaining resources (in terms of items or people), maintaining situation awareness (present and future resources/needs) and seeking out re-supply.

One possible way of meeting the demands for cross-team/organization coordination may be through the concept of boundary spanners (Uhr & Johansson, 2007). Previous research has shown that friendship relations between units inside an organization enhance cooperation. It has also been observed that during actual operations, responders primarily seek cooperation with actors they know. Uhr and Johansson conducted studies during a large-scale
emergency management operation in Sweden. Here, persons who had friendships within other organizations than their own voluntarily acted as boundary spanners, facilitating the exchange of information between organizations, building trust and assisting in situations which had not been covered by scenarios. This could perhaps be utilized to design new work roles, or as a new way of defining leading roles during emergency response. Other researchers discuss a similar concept using the military term Liaison Officer (McMaster & Baber, 2011). These actors are in the same way expected to bridge the gap between teams and organizations, supporting a COP between all involved parts. Militello, Patterson, Bowman and Wears (2007) suggest a similar role for tasks within a team. Here, there is a need for persons who manage and update shared information resources and communicate requests between teams.

While some researchers call for new ways of assessing coordination within and between organizations, some examples already exist in the literature. One is given by Chen, Sharman, Rao and Upadhyaya (2011), who propose a framework directed at the emergency response domain. Five categories of traits are pursued. Task Flow Analysis may be used to uncover interdependent relationships in the process. Continuing, the management of resources and competing demands should be assessed. Collection, analysis and distribution of information should be analysed. Structures, roles and practices concerning decision making should be studied, and finally, an assessment should cover organizational traits in the form of cultures, relationships and group dynamics. Several methods also exist of assessing situation awareness. For example, Schraagen and Van de Ven (2011) used self-rating techniques to measure Team Situation Awareness during crisis management. Similarly, Jensen (2009) has demonstrated that sensemaking in emergency command may be measured. In her study, the quality of plans made stood in relation to the quality of sensemaking.

**Engaging the general public**

The first person at an incident site is often a bystander, who then becomes a lay first responder. This means that the victim is dependent on the bystander’s skills in giving life support care, or in other words, the bystander’s response (Brodsky, 1984).

In the scientific literature, the term „responder“ mostly refers to employees of rescue organizations. To these responders, everyday incidents are a normal part of work, and they have established routines for dealing with them. However, for lay responders these routine events may be perceived as very extraordinary (Danielsson, Johansson & Eliasson, 2010). In the scientific literature of disasters, voluntary organizations have been given extensive attention (Demarin et al., 2010). Yet, assistance from voluntary organizations and lay responders are almost non-existing in the scientific literature of everyday incidents. Studies regarding the general public at incident sites mainly focus on the perspective of the administrative authority, emphasizing on how to handle and organize the general public (Demarin et al., 2010).

To a lay responder, uncertainty due to lack of equipment and physical closeness can be assumed to be present in most incidents. This uncertainty also demands some level of resourcefulness. Indeed, people are in general resourceful. For example, Mannberg-Hedlund (2003) found that patients awaiting emergency services took action to try to ease their pain, facilitate their breathing etcetera. Nelson (1977) studied helping roles in emergency and everyday behaviour. He found that people were likely to help on a variety of levels in
emergency situations. Moreover, in large emergencies such as disasters, people seldom panic, instead they try to help each other (e.g. Drury, Cocking & Reicher, 2009; Levine, Prosser, Evans & Reicher, 2005; Quarentelli, 2006). This helping instead of panicking behaviour may be found in everyday incidents as well, and response systems may be able to use this as a resource.

Traditional research on bystanders, „the bystander effect”, states that the more (passive) bystanders that are present at an incident site, the less likelihood of bystander intervention (for review see: Fischer, Greitemeyer, Kastenmüller, Krueger, Vogrinic & Frey, 2011). Recent research on bystanders has found that bystander behaviours are much more complex and that the above mentioned relation between bystander numbers and interventions does not always hold (e.g. Levine & Crowther, 2008). In fact, Levine, Taylor and Best (2011) found that bystanders in violent contexts were more likely to pacify than escalate when group size increased, and according to Fischer et al. (2011), moral courage may also become more intense with an increased number of bystanders.

Lay responders first have to collaborate with emergency services when calling the emergency dispatch centre. This collaboration has its foundation in the reciprocal perception of the lay responder and the emergency dispatch operator, in other words, their interaction and exchange of information (Danielsson, Johansson & Eliasson, 2010). The first „physical” collaboration at the incident site is, according to Danielsson, Johansson and Eliasson, most often initiated by the lay responder, when he or she continues with the actions already started before emergency services arrived. In her Master thesis, Ek (2009) found that the presence of significant others could be useful as a support for the patient, and that these persons may also provide an extra pair of hands for rescue services. However, in the same study, Ek also noted that significant others sometimes produced a more stressful situation. In addition, Mannberg-Hedlund (2009) found that victims often called their significant others instead of or at least before they called emergency services. In many cases it was the significant other who placed the emergency call.

Some research results suggest that collaboration between lay responders and professionals may be limited by the latter. At the site of the incident, people passing by may feel obligated to call the emergency dispatch centre to report the event. However, continuing the intervention such as starting pre-hospital care may be seen as interfering or even wrong (Brodsky, 1984). In fact, ambulance personnel often see the actions by bystanders at incident sites as questionable (Danielsson, Johansson & Eliasson, 2010). Collaboration between professional rescue organizations and lay responders and bystanders is characterized by boundaries and exclusion rather than interaction and inclusion (Danielsson, Johansson & Eliasson, 2010). Professional rescue personnel often disregard, exclude, or simply do not acknowledge lay responder or bystander presence at the incident site. This often leads to the layperson feeling awkward. They become unsure of whether their presence at the site is needed, and because of that they leave the incident site early (Danielsson, Johansson & Eliasson, 2010). In summary, lay responders and bystanders are most often seen as an unreliability that can do more harm than good.

Fischer et al. (2011) highlight findings showing that the bystander effect is often absent when a situation is perceived as dangerous, or when bystanders are perceived as competent. To a lay responder, due to the extraordinary situation, an everyday incident may
be perceived as dangerous, and through general public first-aid training more bystanders may perceive themselves and others as competent. The research referenced by Fischer et al. also showed that in situations that were perceived as less dangerous, help was given more often in a solitary condition than with other bystanders present (Fischer, Greitemeyer, Pollozek & Frey, 2006).

Most of the scientific literature on bystanders is occupied with violent contexts (e.g. Levine, Cassidy, Brazier & Reicher, 2002; Levine & Crowther, 2008) such as rape or assault. However, since bystanders are often the first persons at an incident site, strong arguments could be made for the study of bystander participation and of the general social context of everyday incidents.

Venema, Groothoff and Bierens (2010) examined pre-hospital care given by bystanders, with a focus on the bystander’s role in drowning incidents. They concluded that rescue and resuscitation actions by bystanders played a crucial part for survivability of victims. Pelinka, Thierbach, Reuter, and Mauritz (2004) studied how often and how well bystanders performed pre-hospital care, and whether bystanders were affected by their levels of training, relationship to the victim and the number of other bystanders present. They found no differences in the performance of life support care as a result of the relationship between the bystander and the injured. Neither were there any differences in most of the measures executed by the bystander as a result of the number of other bystanders. However, they did find that the higher level of first-aid care training in the bystander resulted in an increase of performed and correctly performed necessary life support given to the victim.

Jayaraman, et al. (2009) studied pre-hospital care and first-aid training in Kampala, Uganda, where the police, taxi-drivers and community leaders are the ones most often giving the pre-hospital care. They found that after six months of context-appropriate first aid training, responders felt more confident in giving pre-hospital care, and also found training to be very useful. Another study performed by Mock, Tiska, Ado-Ampofo and Boakye (2002) in Ghana amongst truck-drivers showed that after first-aid training the use of pre-hospital care skills increased by 28% in 10 months.

Another third party (even though not a bystander in the traditional sense) often present at accident sites, sometimes even before rescue services, is the media (Lundälv, 2003). All personnel working an accident site needs basic training in first-aid skills, thereby also including media personnel (Lundälv, 2001). Lundälv (2001) further argues that the training of media personnel should be theoretical as well as practical.

In summary, if fellow bystanders are perceived as competent and supporting, the likelihood of bystander intervention increases in a critical situation. If on the other hand fellow bystanders are perceived as passive, the likelihood of bystander intervention decreases. The social context thereby seems to be an important factor in helping responses in critical situations. It is also possible that if the general public was to receive basic first-aid training to a larger extent, this could facilitate helping behaviours and make bystanders, lay responders, more confident in their response. Also, with an increase in the numbers of first-aid trained bystanders, there may be a decrease in the number of passive bystanders, as a result of self-efficacy or group-efficacy.

In a study on first responders, Stenborg, Blondin and Andersson Granberg (2010) emphasised the fact that there are voluntary organizations already trained for rescue
situations, and that these may be of importance in achieving more effective response systems. They found fruitful outcomes of the „in-wait-for-emergency services” (Swedish: I Väntan På Räddningstjänst, IVPR) where other professions that receive emergency training were called out to an emergency. Andersson Granberg et al. (2010) notes several professions that may be used as responders in different incidents, such as plumbers, and Stenberg, Blondin and Andersson Granberg (2010) highlights several voluntary organizations. One conclusion emphasized by Andersson Granberg et al. (2010) is that there may be great benefits in collaboration between professional rescue services and professionals outside of the rescue service, and also to develop a functional format for the same.

Another organization already part of the health care system is the community health centre. According to Ablah, Tinius, Horn, Williams and GEBBIE (2008) there are very few studies on the preparedness of community health centres. Studies in this area could explore the possibility of sending emergency response personnel from these centres to less acute incident sites, instead of sending the, according to Berlin and Carlström (2011), „overly strained” ambulance service. Ablah et al. (2008) emphasize that the community health centre is an „overlooked emergency response group” (p. 246).

**Technological and organizational support**

In this section, a number of examples will be provided of research projects that aim to support different parts of emergency response coordination.

The last years have seen an explosion of technologies that may support coordination, such as wireless mesh networks, peer-to-peer communication platforms, sensor networks, knowledge management systems, geographic information systems, communication standards, proactive analysis programs, and systems directly aimed at collaborative work, command and control (Chen, Sharman, Rao & Upadhyaya, 2007). Modern information technology allows for interaction between dispersed operators and can provide a wealth of information. Woltjer, Lindgren and Smith (2006) mention videoconferencing and virtual whiteboard facilities as possible future examples of communication artefacts that provide users with common objects of reference. Militello, Patterson, Bowman and Wears (2007) envision command centres that encourage movement and communication, using shared information displays, allowing for reconfiguration according to changing needs. On the other hand, if systems do not take human cognitive abilities into consideration, they may easily produce information overload (Woods & Branlat, 2010), and many other pitfalls exist within this domain.

Among the coordination-related examples found in the literature, a majority focus on supporting tasks of planning and decision making, taking collaboration and distribution of agents into account. Turoff, Hiltz, Plotnick and White (2008) mention a number of features that a system for group support should display in order to improve decision making. Individuals should be allowed to interact asynchronously and be able to participate in decision processes whenever and wherever they are situated. Furthermore, Turoff et al. suggest that information about the group’s state should be clearly visualized, and that a flexible, anonymous system of voting should be provided. Wex, Neumann and Schryen (2011) distinguish between different ways of providing decision support. Some use methods from statistics and probability theory to supply decision makers with metrics during their work.
process. Others aim to introduce intelligent computer systems, and a third group investigates past crises in search for courses of action that may apply to future events.

As a way of improving coordination at an early stage, Wickler, Hansberger, Potter and Tate (2011) propose the use of web 2.0 technologies, social networks and virtual collaboration environments. Web 2.0 technologies allow users to participate in the creation of shared information resources. In a web-based portal developed by Wickler et al., users are allowed to engage in asynchronous discussions and take part in the development of documentation, as well as in synchronous problem-solving. Participants have profiles and individual blogs, and access to twitter-like information sharing. For specific collaboration needs, I-rooms allow for richer interaction than forums, including different forms of information visualization and voice interaction with avatars. Interactions are guided by collaboration protocols, making users aware of each other’s abilities, aiding them in assigning roles, responsibilities and authority. In experiments performed by Wickler et al., groups that had experienced virtual collaboration formed plans with greater breadth and depth, and they needed less time to establish common ground than regular teams. Although this technology is aimed at distributed crisis response planning, it could very well be envisioned for other uses as well.

A quantitative tool to support decision making is proposed by Drury, Klein, Liu, Moon and Pfaff (2011). Their technology visualizes the decision space for a particular problem in terms of plausible outcomes and weightings, in order to support “option awareness” in collaborative decision processes. Results from experiments show that an increased awareness of combined decision spaces, that is, of synergy effects stemming from interaction between participating agencies, may improve collaborative decision making.

Similar examples are given by Turoff and Van de Walle (2008). The decision support system FURIA makes it possible for individuals to compare their assessment of an option with those made by other group members, providing a base for discussions. Another example on a larger scale is RODOS. This system, evolved after the Chernobyl accident, is meant to provide emergency management with decision support in the case of a nuclear accident. This is achieved by methods of forecasting (e.g. concerning the spread of hazardous materials), suggestions on possible countermeasures, calculations of benefits and drawbacks, and ranking of strategies. A sub-system to RODOS, called Web-HIPRE, has been developed by Bertsch, Geldermann, Rentz and Raskob (2006). This system is also constructed to act as a Multi-Criteria Decision Analysis (MCDA) tool, and is aimed at enhancing the user’s understanding of the problem at hand, what issues may exist, and his/her own problem-related values. Here, a decision problem is structured as an attribute tree, where an overall goal is divided into criteria and attributes. This process follows the concepts of Multi-Attribute Value Theory (MAVT). Preferences of involved decision makers are accounted for in the process, attempting to give as complete a description of the problem as possible. Experiments of Bertsch et al. have shown that this process of collecting, structuring and sorting information provides a deeper understanding of the problem at hand and that plans are consequently of higher quality. It may however be put to question whether this type of activity is feasible in an emergency operations context, given the high time pressures involved, and whether the positive effects seen may simply stem from the collaborative process itself (much like the situation with plans and planning processes referenced above). Bertsch et al. mention this
possibility themselves, noting that workshops promoted communication and created a shared understanding between the parties involved.

Wex, Neumann and Schryen (2011) aim at supporting the coordination of resources during emergency management. In their 2011 article they direct their efforts at the emergency command centre of large-scale operations, using monte-carlo simulations to process situations involving multiple factors, constraints and types of resources. Their results are promising and suggest that similar methods could be used despite limitations in time.

Comfort (2007) chooses a non-technical route, suggesting that decision makers may benefit from a critical-thinking technique. This technique is meant to help professionals overcome biases such as framing bias, confirmation bias and tunnel vision, and recognize unfamiliar and problematic situations. In a way similar to Reason’s concept of mindfulness, Comfort means that this could help improve situation awareness. If critical thinking was to be made into a collaborative process it could be used to scrutinize plans and assessments during emergency work, revealing uncertainty and its origins in order to handle it. A simple tool, called the Critical Thinking Tool (CTT), has been conceptualized for this task. In brief, users of CTT colour-code evidence supporting different interpretations of a problematic situation.

For several years, the US government has been employing „public safety officers”. These persons cover a variety of responsibilities in public safety, such as fire-fighting, emergency medical assistance, water safety, law enforcement, search and rescue and so forth (Wood, 2002). The introduction of this occupation was at first protested by emergency service personnel (Chelst, 1988). This can be compared to the „unwillingness” to collaborate between rescue organizations found in several studies (e.g. Berlin & Carlström, 2011; Danielsson, Johansson, & Eliasson, 2010; Forland, Zakariassen & Hunskår, 2009). To implement this in Sweden, which could be beneficial in for example rural areas, solution-based research in collaboration between rescue organizations is needed to be able to develop a well-functioning response system function.

**Information and communication**

Successful coordination depends very much on effective communication, because of its role in creating shared understandings (Comfort, 2007). Issues in communication, such as unclear communication paths, have been identified as major problems in several large-scale emergency operations (Lundberg & Asplund, 2011). While some of the solutions described above will facilitate communication, and while it relies on well-designed information systems investigated in later sections, this section will deal with certain traits of communication that do not fall under either category.

Technology for information and communication (ICT) has the aim of gathering, processing, distributing and mediating information (Woltjer, Lindgren & Smith, 2006). Comfort (2007) describes asynchronous dissemination of information as a major issue in multi-agency coordination, something that leads work-teams to act without regard to the activities or states of others. As noted earlier, relief workers in public safety networks often run into problems because access to information is limited, or because information is not shared effectively (Bharosa, Janssen & Tan, 2011). Comfort (2007) holds that our capacity to recognize risks depends on information that is well-timed, accurate and valid, and thus relevant for a particular responder at a particular time. Balancing this against the danger of
information overload is naturally a difficult challenge. As noted before, while it may seem like a good thing to supply every team member with all the information needed by the whole team, this can easily produce problems (Bergström, Dahlström, Henriqson & Dekker, 2010; Salmon, Stanton, Jenkins & Walker, 2011). Instead of trying to predict future events, teams become preoccupied with adding detail to mission history, something described as “paralysis by analysis” by Bergström et al. Furthermore, timing of information may be vital. Information that is delivered too late may obviously not reach its full effect, while information that is delivered too early may run the risk of being neglected (Janssen, JinKyu, Bharosa & Cresswell, 2010). These were problems encountered during the aftermath to hurricane Katrina, and to counter them, Comfort (2007) envisions an inter-organizational information infrastructure for search, exchange and feedback. This view is supported by Jungert, Hallberg & Hunstad (2006) who similarly suggest that interoperability must be one of the foremost features of an information system for crisis management.

**Requirements for communication**

Research has shown that effective teams display certain traits in communication (Schraagen & Van de Ven, 2011). Their members share information in a clear and accurate manner, follow agreed-upon forms for communication, use the right terminology and provide consistent feedback. But there are also facets of communication that serve to direct, accentuate or even transmit messages, without involving verbal interaction. It has already been mentioned that within-team coordination depends partly on informal verbal communication, gestures and gazes (Latiers & Jacques, 2009). These and other socializing interactions may be supported through careful design of command centre environments, but it may be much more difficult to incorporate them in communication mediated by information technology (Woltjer, Lindgren & Smith, 2006).

Johansson and Persson (2009) conducted interviews with UN personnel about their experiences from sharp missions in foreign countries. These researchers hint to a possible fallacy in communication systems design, by noting that human communication often answers needs that emerge in unique situations, while technology for communication is structured according to needs that can be predicted. Johansson and Persson argue that we must understand all the social mechanisms associated with human interaction, where communication is very much a matter of building relations and trust. Such an understanding is vital if we are to support communication, coordination, and ultimately control. Woltjer et al. (2006) argue that collocation, that is, face-to-face work at the same location, allows for the creation of common ground and trust, leaving room for flexibility in interaction and task allocation. Designers of emergency management systems should take this into account and try to meet these needs through interface and information system design, but it may also be beneficial to incorporate as much collocation as possible during emergency management. For example, interviewees in the study by Johansson and Persson noted how much easier it is to engage in distance communications with a person if a social relation exists. This may help to lessen our uncertainty around how a message is received.
Supporting communication

It has already been suggested that modern information technology does not always give all expected benefits. Instead, it may at times create fragmentation and isolation among responders from different agencies. In Sweden, for example, the introduction of mobile phones and separate communication systems has made it harder for responders to share information and keep track of the activities of others (Berlin & Carlström, 2011). A recent article describes how a related theme has been explored in Finland (Norros, Colford, Hutton, Liinasuo, Grommes & Savioja, 2009). The Incident Commander is the person in charge of multi-agency operations at the accident site, and the aim of this project was to support that particular role. Taking off from a JCS perspective, Norros et al. set out to analyse how a Common Operational Picture is formed among fire fighters. Results show that the Emergency Response Centre is vital for the creation of a COP, and that between-agency communication depended heavily on a TETRA network for communication. The Incident Commander, however, relied mostly on his memory and his interaction with the IC vehicle driver for cognitive support.

Dugdale, Darcy and Pavard (2006) conducted studies among first responders in emergency interventions, showing that lack of good communication was the most important cause of disruption during work, causing a lack of information at the Command Post (CP). To counter this, Dugdale et al. are attempting to use distributed WiFi transmitters (a MESH network) in order to grant functioning communications regardless of where first responders are situated. This type of technology will be revisited later under the heading Information System Resilience. Mesh network technology has also been suggested as a remedy to the fact that common walkie-talkie communication does not scale very well above smaller teams, something that became apparent during the 9/11 attacks (Panitzek, Bradler, Mühlhäuser and Schweizer, 2011). The study by Panitzek et al. makes a strong case for the importance of well-functioning first responder communications and will later be referenced when discussing Mesh networks.

Modern network technology allows for the use of a variety of media in communication, such as text, speech, images and videos. But as responders work to handle an adverse event, their needs will change over time. For example, responders capturing and transferring video will need a large bandwidth while other may not. Lass, Regli, Kaplan, Mitkus and Sim (2008) try to tackle this problem by using different techniques of dynamic Distributed Constraint Optimization (DCOP). These are algorithms to manage the flow of information inside a network, in order to provide an optimal distribution of channels and bandwidth for all involved parties.

Few examples have been found where researchers try to merge online communication with the advantages of face-to-face collaboration referenced above. The research on virtual collaboration environments by Wickler, Hansberger, Potter and Tate (2011) has already been mentioned, but this technology is primarily aimed at the preparatory phase of emergency response. It may be interesting to investigate whether some specific traits of face-to-face communication should be pursued in online interaction, or whether the benefits of collocation can be separated from the collocated setting and introduced online.
**Information systems requirements**

Salasnyk and Lee (2006) review past attempts to integrate information systems of different agencies and provide an extensive list of functions that a unified system should support. According to them, information sharing between organizations often fails because of lacking system interoperability. This inhibits the flow of information and makes it harder for units to coordinate their efforts. System applications have often been found to be isolated, fragmented and overlapping in content and functions. It is common that responders are unaware of the situation for other agents within their own agency, and naturally, the situation is often much worse concerning cross-organizational understanding (Janssen, JinKyu, Bharosa & Cresswell, 2010). Bharosa, Janssen and Tan (2011) describe these kinds of issues in terms of *information quality*, a property related to information coordination. Here, coordination of information refers to collection, analysis, enrichment and distribution of information. Salasnyk and Lee also note that there is often a resistance to change among agencies and lacking understanding of the needs of other organizations. Furthermore, sharing information can also be associated with certain issues around information security. In Sweden, as soon as the victim is under medical care the Health Act (Hälso- och Sjukvårdslagen) is in effect, which states that the incident site is transformed into an emergency room. As this transformation occurs, further legislation applies, the Official Secrets Act (sekreteresslagen) (Lundälv, 2003). Therefore, modern information technology must be combined with measures to secure the integrity of patients in out-of-hospital care.

In Salasnyk and Lee’s 2006 study, simulations were carried out to investigate the impact of information transfer times on overall efficiency, and it was demonstrated that data integration could cut information transfer times for call centres by half. In summary, there is a strong case to be made for technological converge among agencies (Reuter, Pipek & Müller, 2009).

Van de Walle and Turoff (2008) refer to earlier work by Turoff, providing some general guidelines concerning the design and specifications of a well-functioning information system, or a Dynamic Emergency Response Management Information System (DERMIS) in the words of the authors. Here it is argued that functions in the ERS should be used for everyday incidents as well as for large-scale crises. This will avoid mismatches between practices and tools and allow everyday operations to serve as training for more extreme events. Continuing, a system should be able to filter information carefully, so that every user receives neither more nor less than what is needed. However, all users must still be able to access all information, stored in a centralized database, because filtering processes will not always function optimally. Users must also be allowed to exchange information freely, so that they can distribute authority and share situation awareness. Furthermore, the system should log events without producing more work for its operators. Doing so will provide a rich base for post-crisis learning. Finally, since flexibility has been identified as a key feature of efficient emergency response, an information system should allow for uncomplicated re-planning and re-allocation of resources during operations.

Taking a slightly different approach, Borges, Engelbrecht and Vivacqua (2011) discuss the implementation of digital tabletops in emergency situations and investigate the needs of different roles during emergency response. At the command post, artefacts should support collaboration and flexibility between individual and collaborative work. Results of
work at different stations should be transparent and clearly visualized. Professionals at the CP may find it hard to develop an awareness of incident-site circumstances, so it is vital to supply information about changes, difficulties, victims and resources at the location. Here as well, the importance of information needs and filtering is mentioned. Different roles have different needs at different times. Borges et al. suggest that a digital tabletop is suitable for this environment because it holds affordances for collaborative work. This table could also be combined with synchronized tablets allowing for temporary mobility. Information about changes, resources and so forth is equally important for on-site commanders. First responders meet other challenges. For them, mobility of information artefacts is of utmost importance, and the situation may make it hard to use the hands to manipulate detailed interfaces.

Bowman, Graham and Gantt (2007) direct their attention to the incident commander, discussing the implementation of robust, mobile communication devices. These devices should allow for both voice and data communications between organizations and should make it possible to present documentation such as procedures and guidelines. They should also allow field operators to update centrally stored information. Modern technology may also enable creative graphic visualization and navigation.

Following a theme similar to that of Bowman et al. (2007), Comfort, Dunn, Johnson, Skertich and Zagorecki (2004) analyse information system requirements for incident commanders. Five important factors for incident command are identified. Firstly, commanders depend on reliable and systematic information exchange both within and between organizations. Secondly, in order for risk assessment to be possible, information has to be accurate and timely. Thirdly, information must flow easily between jurisdictional levels of operations. Fourthly, commanders must be able to monitor threatening conditions in real-time, and information transfer between field operators and commanders must be timely. Finally, in the event of a large-scale crisis, commanders must receive reports from all sites of operation, and this information must be integrated into a meaningful whole.

**Existing systems and tools**

Dorasamy and Murali (2011) give numerous examples of recent information systems projects related to crisis response, such as Turoff’s DERMIS, The American NIMS, Google’s Person Finder Tool, and a number of other systems primarily aimed at disaster scenarios. Although these systems tend to deal with the distributed collaboration of both private organizations and governmental agencies, focusing on factors like early warning, risk areas, locating of victims and so on, they could likely provide inspiration for everyday ER systems as well. Dorasamy and Murali specifically discuss Knowledge Management Systems (KMS), stating that KMS is still a quite novel concept within emergency management. KMSs should allow people to create, capture, codify, store, share and apply knowledge. This may involve document management, semantic networks, databases, decision support systems, expert systems and simulation tools. In particular, these researchers argue that knowledge management could help to maximize lessons learned from past emergency events, by for example utilizing Wiki technology.

In the US, FEMA has launched a web-service called Collaboration, where agencies can share lessons learned from emergencies by interacting in a virtual world (Kapucu, Tolga & Demiroz, 2010). Another large-scale project mentioned by these researchers is NEMN,
developed in the private sector. This system is compatible with NIMS and aims to support collaboration, communication and training for distributed stake-holders during an emergency.

Camarero and Iglesias (2009) describe the creation of an online tool to make information about disasters available to the public. Web 2.0 technologies make it possible for both ER actors and private citizens to contribute to shared information, communicate and organize socially online. Examples are given of successful past examples. One is the “San Diego Wildfires” project which made it possible to follow active fires on a map. Camarero and Iglesias’ project also incorporates mapping, allowing for social participation and interactive management of disasters.

Comfort et al. (2004) present a system prototype which is more directly suited for everyday emergency response. Participatory design is utilized, involving response commanders to specify required functions. This Interactive, Intelligent, Spatial Information System (IISIS) provides real-time communication between teams and agencies. Users have ready access to databases, enabling them to update information about emergency situations. The system also incorporates a Geographic Information System (GIS) for mapping events and response, and computer-supported probabilistic risk assessment based on information about populations, infrastructure and specific community vulnerabilities. GIS support is similarly mentioned by Kapucu, Tolga and Demiroz (2010) as a very valuable tool for enhancing situation awareness among decision makers. Further decision support is provided through calculations of time, cost and consequences of different response strategies. These calculations are based on priorities and risks specified by commanders.

Apart from technological solutions there are also organizational concepts that could help information sharing between teams and agencies. One that has already been mentioned is the use of so-called boundary spanners, persons who are specialized in cross-team/organizational communication, perhaps through personal contacts within other agencies or teams (Bharosa, Janssen & Tan, 2011). These persons would, in the words of Bharosa et al., conduct information orchestration (finding, prioritizing, combining, evaluating and sharing information) using modern information technology to coordinate activities.

Besides timing issues, information overload has been mentioned as a likely problem when modern information technology is used for emergency response. While some attempt at filtering or manual management, Fitirianie and Rothkrantz (2008) experiment with a dialogue system to relieve crisis hotline dispatchers when workload is high. The system described in this article uses both content, context and caller emotions in its response, comparing input to a database over keywords in order to assess urgency of the call. Some limitations exist. For example, problems arose during tests when callers wanted to report events outside of the scope of the database used. At these times the system’s functioning did not degrade gracefully.

Landgren (2005) notes that everyday emergencies often call for a hasty response. This makes the time spent travelling to the location important for understanding and preparation. Ideally, Landgren states, support should be provided for mutual representation, where the incident commander and central command share a representation of the current situation. This researcher carried out situated observations during emergency response and produced requirements for information artefacts in the field. These should incorporate positioning and well-designed maps, contextual information about the environment and other descriptive
information (e.g. about local businesses), and information from sensory systems like fire alarms and surveillance cameras. Landgren envisions that an enriched information environment could change the work roles of local and central commanders, but because this article does not describe any actual implementations, it is simply noted that visions do not always match the actual effects of new technology. This became clear in a study by Granlund and Granlund (2011). These researchers studied whether providing GPS information for command centre and command post had an effect on team collaboration. Experiments were carried out in a micro-world simulation environment (C3Fire). It was expected that this additional information would support work, but results suggested otherwise. GPS data may have produced a higher workload for commanders. This had effects on both response time and performance, because time was spent on evaluation that in normal cases would have been administered to other tasks. Furthermore, participants using GPS information communicated less than control teams, because command relied on this artefact to carry all relevant information.

Brons, De Greef and Van der Kleij (2010) describe a tool under development aimed at improving what they call activity awareness, a concept clearly related to situation awareness, with a focus on the activities of others. These researchers suggest that when co-located work is not possible, teams could be helped by displays updating them on the current activity, status and workload of other teams. At the time of this short paper no experimental results are available.

Using a more low-tech approach, De Koning, Huis in ’t Veld, Kuijt-Evers, van Rijk and Theunissen (2011) attempt to support situation awareness with a guide to be used by emergency management personnel. This guide, taking the form of a checklist, is meant to help responders decide on the timing of sharing information, and whether a particular piece of information should be shared with other teams or agencies. Results from tests, however, show that neither competence nor situation awareness was improved. Participants did however report a higher satisfaction from meetings and a greater focus on information sharing.

It has been mentioned that proper timing of information is both important and difficult to achieve. Cimiano, Hadders and De Lignie (2011) present a rule-based system for delivering timely information to first responders. This is part of a larger project called MOSAIC, which aims to enhance situation awareness for police officers. Some previous examples are mentioned that use temporal or spatial cues and it is stated that a common problem resides in the filtering of information. In the present project, typical response situations were identified and divided into phases, or sub-activities, which were used as a context for determining when certain types of information should be presented. Which phase responders are in could be reported by the responders themselves or elicited from central communications. In this paper, the weight is placed on the development of related software and not on an actual tool for use.

Norros, Liinasuo and Hutton (2011) direct their attention toward supporting a Common Operational Picture among responders. The researchers behind this study used a creative approach, letting two groups of experienced emergency responders work in parallel, dealing with a realistic emergency situation. Information from the aided team was used to determine what useful information could be provided by sensor technology (ammonia-sensitive sensors), a wireless sensor network, and visualization of chemical concentrations on a laptop computer. Systems were developed using rapid prototyping, in close collaboration
with users. Results show that communication load decreased when sensor information was available, that aided teams became better at identifying hazards, that operational decisions for assisted groups were of higher quality, and that these teams were more aware of potential chemical diffusion into the surrounding environment.

In a recent ISCRAM report, Bakopoulos, Giannka, Prasad, Tan and Tsekeridou (2011) describe the development of an application for command and control, referred to an a Situational Awareness System. This system is meant to integrate and visualize information from a wide array of sources, such as cameras, sensors and PDAs of on-site users. It also allows for administration and manual input of data, as well as for communication and coordination among responders. One modern feature is the ability to maintain communications and track users below ground or in buildings, something that is not possible using traditional GPS technology. This is accomplished using RFID tags and an ad-hoc WiFi network. The subject of these kinds of networks will be revisited in the following chapter.

After information has been gathered and filtered, the question arises of how data should be visualized. The form and content of messages may affect the workload of emergency responders (Lundgren and Asplund, 2011). Personal digital assistants (PDAs) have been becoming increasingly robust, which makes it possible to use them in very harsh environments, for example by first responders (Maciejewski, Kim, King-Smith, Ostmo, Klosterman, Mikkilineni, Ebert, Delp & Collins, 2008). In the study by Maciejewski et al., a mobile visual analytics tools has been developed. 2D and 3D visualization is combined to display situational information and other data relating to the scene. These researchers are particularly interested in the choice between 2D and 3D imaging, where each mode carries with it benefits of its own. Multi-media playback capabilities make it possible for responders to share video and images over a network. Agents are tracked using GPS, or when indoors, using 802.11 network arrays. Maciejewski et al. give several examples of past research attempting to support front-line agents through augmented reality technology or other mobile devices, for example during mass events.

Sensor technology is also the interest of Purohit, Sun, Mokaya and Zhang (2011). They note that static sensor networks may be impractical because they demand a large, maintenance-demanding infrastructure. Furthermore, permanent sensor networks may not be accessible to responders, and their coverage may be limited. Purohit et al. instead suggest a mobile sensor network, where nodes deploy autonomously and can easily be replaced and reorganized. A number of previous examples are mentioned and the researchers also present a prototype of their own. This system, named SensorFly, allows robust and relatively cheap sensors to cover areas by flying (or rather leaping), providing spatial data and information on fire propagation. Problems exist, for example related to battery capacity and traversing environments that are blocked.

Even though we live in a world where mobile-cellular subscriptions have reached 5.9 billion (International Telecommunication Union, 2011) there is surprisingly little research in the scientific literature concerning benefits from the use of this technique in everyday incidents. Today, most mobile-cellular phones have a camera, which could provide crucial information for emergency services. Lundälv (2003) argues that photos taken at the incident site, both of the victim and of the actual site, may be of assistance to the receiving doctor at the emergency room. In traffic-accidents, for example, photographs could help doctors
evaluate the strength of crash violence, and they could also help the police in their post-incident investigation.

Bolle, Hasvold and Henriksen (2011) found that bystander use of video calls from mobile-cellular phones improved communication during medical emergencies. The use of video-calls would make it possible for the emergency dispatch operator to see and evaluate the victim and incident site. This would make it possible to send more accurate information to rescue organizations, and to give the lay responder more precise and appropriate instructions in life support measures. In addition, video-calls may decrease the lay responder’s feeling of being alone and increase his or her confidence in the life support actions that need to be executed. The use of video-calls in everyday incidents is thereby of relevance for ERS research, since it may improve the quality of pre-hospital care given by the lay responder (Bolle, Hasvold & Henriksen, 2011). Another advantage with the use of video-calls from the incident site could be to allow first professional responders to review the situation before they arrive. Also, the use of video-calls may facilitate the exchange of information between on-site emergency personnel and command, which may reduce strains and increase collaboration.

Finally, one creative attempt to minimize the time elapsed between an accident and response is to use modern smartphones as sensors. This path is explored by White, Thompson, Turner, Dougherty and Schmidt (2011), who are developing a smartphone application called WreckWatch. This software is capable of providing information on travel path, speed and forces of acceleration during a traffic accident. The app can also be used by bystanders to supply responders with textual information, images and video. While problems exist, such as false positives caused by falling phones, it is argued that information gathered during the accident can provide valuable support for first responder situation awareness.

**Information systems resilience**

It has been mentioned several times in preceding chapters that emergency response is an activity associated with high levels of uncertainty, and that demands for responder flexibility are high. This has the natural effect that technological systems used in this context must be equally flexible and robust.

In emergency response research, recent years have seen an increased interest in Mobile Ad Hoc Networking (MANET). This technology allows a collection of portable or stationary computers to form a network of their own and serves to counter uncertainties around coverage or damage to infrastructure. It also makes it possible for responders to maintain their connection underground or indoors. Combined with Peer-to-Peer (P2P) technology, where devices share the handling of each other’s requests, such systems for communication can become very flexible and resilient (Kanchanasut, Tunpan, Awal, Das, Wongsaksakul & Tsuchimoto, 2007). DUMBONET, created by Kanchanasut et al., combines MANET technology with a satellite IP network and conventional terrestrial internet to give users tools for coordination, communication and information management. The next step in their research is to add the use of mobile sensor equipment to DUMBONET, both to help situation awareness and to decrease risks for responders. Research on the same theme was carried out by Oliveira, Sun, Boutry, Gimenez, Pietrabissa and Juras (2011). The MONET project is funded within the EU and is directed at optimising hybrid ad hoc and satellite network, which is also the theme of the article by Oliveira et al. Using satellite technology may be
unavoidable in some situations and can always make up a last resort if other networks fail. In this study, questions are raised around whether the management of network access points should be centralized or performed in a distributed network. It is also noted that satellite communication is associated with high latencies and delays, which may create problems for communication.

Another concept aiming at functionality similar to that of MANET is Mesh Networks, using distributed WiFi transmitters (Dugdale, Darcy & Pavard, 2006). Dugdale et al. describe one project using so-called mesh boxes to improve communications between on-site responders and the command post. Mesh networks allow for graceful degradation because of their flexibility, and can offload operators through automatic optimization. Panitzek, Bradler, Mühlhäuser and Schweizer (2011) present a slightly different approach under the name City Mesh. In this project, a network for crisis response is supported by portable devices, stationary access points and communication vans. However, voluntary participation may also be sought from public wireless networks (e.g. in cafés) and handheld devices or home networks owned by citizens. Together, these resources may form the backbone for city-wide emergency management network access. Similar networks have been tested at MIT (MIT Roofnet Project) and in Aachen, Germany (Mobile ACcess). Dugdale et al. (2006) even suggest that private computers in such a network could be utilized to perform demanding data processing, thereby off-loading the equipment used by first responders. Experiments seem to suggest that this type of network can be robust, but naturally, privacy issues for involved citizens need to be addressed.

If no network infrastructure exists and satellite communications are too limiting, responders may have to bring their own network equipment. Bowman, Graham and Gantt (2007) have developed a moveable information and communications hub which is suitable for installation in the boot of an SUV. This hub, called MITOC, is a collection of technologies, including satellite voice and data communications, portable phones, WLAN and laptop computers. Special care has been taken to support collaboration, allowing for interoperable communications between organizations and agencies. Information can be managed in the field, mapping and other documentation is available, and tools exist for intelligence analysis and decision support. In particular, Bowman et al. have worked to develop standardised techniques and procedures for its use. Tests have revealed that bandwidth is a central need for users. MITOC has seen a number of successful implementations. In the future, these researchers envision the use of low-cost UAVs to transport sensors, wireless access point or surveillance equipment.

**Handling uncertainty**

When first responders answer a call for their services, there is often little chance of knowing how the particular situation will evolve. Both known and unknown variables may interact, so that a seemingly small incident quickly develops into a large-scale hazard (Taber, 2008). While this calls for flexibility, an organization also needs stability in operations. Maintaining a balance between the two means working at the „edge of chaos”, where work is structured enough to ensure efficient communication and coordination, and flexible enough to adapt when circumstances change (Comfort, Dunn Johnson, Skertich & Zagorecki, 2004). Resilience has been referred to as a key to success when working under uncertainty (Nemeth,
Wears, Patel, Rosen & Cook, 2011). In the preceding section, a number of examples were given on how technical systems for information and communication can be made more resilient. But what other factors may influence a sociotechnical system’s overall capacity to foresee, handle and recover from disturbances? In this chapter, research will be presented that attempts to answer this question.

An organization may try to counter uncertainty through a strictly governed work process, where premade plans are used in an attempt to cover for all thinkable future scenarios. However, this kind of foreseeability has proven hard to accomplish (Rankin, Dahlbück & Lundberg, in press), and relying too much on plans may lead to inflexibility when things do not happen as expected (Chen, Sharman, Rao & Upadhyaya, 2011). Rankin et al. (in press) stress the ability of responders to improvise when plans do not provide sufficient support, for example by modifying procedures. These researchers performed a case study on a Swedish response team carrying out a role-playing exercise. It was found that performance was heavily affected by lack of language skills and domain knowledge, but also by structural problems, such as insufficient work role definitions, lacking handovers and inefficient communications. Previous research is cited connecting improvisation to training, resources and skills. In the light of this, Rankin et al. suggest that performance could be improved by training to take on different work roles, clearer responsibilities and structured handovers. It is also mentioned that technology must allow for information sharing within the team.

Research within the healthcare domain has shown that while tight procedures often aim to increase control, the effect may very well be the opposite (Nemeth, Wears, Patel, Rosen & Cook, 2011). This theme is adopted by Grote, Weichbrodt, Günter, Zala-Mező and Künzle (2009). They note that routines may provide a valuable organizational memory of the lessons learned from past events, and that they also may improve coordination. However, uncertainty means that something also has to provide flexibility in the work process. Grote et al. suggest that flexible routines could make up a middle ground between stability and adaptability. If rules and regulations are regarded more as starting points rather than as complete scripts, operators may be given enough freedom to cope with sudden demands. At the same time, it will make them able to contribute to a shared pool of work-related knowledge. A similar theme is also discussed by Windischer, Grote, Mathier, Meunier-Martins and Glardon (2009). Empowered sharp-end operators and de-centralized decision making may have to substitute traditional hierarchies when time is short (Janssen, JinKyu, Bharosa & Cresswell, 2010). However, if routines are to be objects of constant renegotiation, certain risks may follow. For example, McMaster and Baber (2011) note that although improvisation both regarding organizational structure, coordination and roles may be vital for mission success, it may also invite misunderstandings between units in a large-scale operations. Grote et al. (2009) see the practical implementation of these concepts as an important future area of study.

According to Turoff, Hiltz, Plotnick and White (2008), maintaining resilience may not only be a matter of artefact design, but also of a certain creativity among responders. These researchers believe that training could equip persons in the field with mental abilities to cope with uncertainty, a view also held by Voss and Wagner (2010). One article by Mendoça and Friedrich (2004) is concerned with how training may prepare people to improvise when they encounter unplanned-for situations, a type of real-time procedure design similar to the
concepts discussed by Grote et al. (2009). Mendoça and Fiedrich state that training should be realistic, for example with regard to time pressures, and focus actively on how to recognize and meet situations that demand improvisation. Simulation-based training is suggested, as well as adapting computer-based tools used in the field to support improvisation. This could for example be a matter of information handling and decision support. Eriksson (2009) describes the response to Hurricane Gudrun in Sweden 2005. Research has demonstrated that disaster training prior to the hurricane did not match the seriousness of the actual event. Scenarios used for training did not come close to the aftermath of Gudrun, and its mere extension in time was surprising. To counter this, Eriksson holds that teams should engage more in joint drills and risk analysis, providing knowledge transfer to actual emergencies. In the following chapter, this theme of training and learning will be explored in an emergency response system context.

**Training and learning**

Although the present study primarily deals with the response phase of emergency management, this chapter will explore research that deals with training for emergency response. The rationale behind this was hinted in the previous chapter, where it was suggested that efficiency of operations in sharp situations depends heavily on the modes and structure of training. Furthermore, many of the methods used in modern emergency response training are also important tools in ERS research and development. McNeil and Quarentelli (2008) argue that in dealing with disasters there is a focus on written documents. Instead they promote processes such as education for the public, interaction between groups, training and involvement from the public.

Emergency management requires responders to act quickly and creatively under strong time pressures and with limited resources. This means that emergency response systems must be built around these actors (Aedo, Bañuls, Canós, Díaz & Hiltz, 2011), and that training must allow them to fulfil all the needs identified in previous chapters – Coordinating work both within and outside of teams and organizations, communicating efficiently, managing information, adapting and making good decisions. If designed correctly, collaborative training allows different agencies to develop valuable relationships (Woltjer, Lindgren & Smith, 2006). It can also compensate for asymmetric knowledge and experience (Militello, Patterson, Bowman & Wears, 2007) and make it possible to take full advantage of lessons learned from past experiences (Turoff, Hiltz, Plotnick & White, 2008). In the literature, the term scenario is used for framing training methods where a spectrum of possible situations may arise (Reuter et al. 2009). Scenarios may not only serve for training purposes, but can also be used for planning, given that they are realistic (Yao, Turoff & Chumer, 2010). If information systems are shared between agencies, experiences from joint training may also be spread to increase shared understandings of work.

Turoff et al. (2008), together with many other researchers, particularly argue for the use of simulation and virtual worlds in training, for example supported by hypermedia or gaming systems (Reuter, Pipek & Müller, 2009). These tools make it possible to model many features found in real-life emergency response, such as complexity, coordination, artefact use, communication, surprises and physical distribution of actors. Responders can experience situated learning, experiences are easily recorded, systems can allow for endless variety, and
people in different locations may collaborate online (Aedo, Bañuls, Canós, Díaz & Hiltz, 2011). Realism and unpredictability in training can make responders more mindful about their work, which in turn will improve their cognitive flow in stressful situations (Campbell, Huseyn, Furness, Weghorst & Zabinsky, 2008). Participants can be subjected to unexpected events, something that can later be used to inform the design of supporting artefacts (Adderley, Barnett, Smith, Westley & Wong, 2011). In addition, Beaman, Barnes, Klentz and McQuirk (1978) found that students who had participated in a lecture on the bystander effect were more likely to intervene in a critical situation than students who had missed the particular lecture, something that points to the importance of education and information.

Apart from its obvious value in training, simulation may also be an efficient tool for response system development, because experiences drawn from exercises may reveal unexpected demands in real-world contexts (Norros, Liinasuo & Hutton, 2011). Other researchers, like Latiers and Jacques (2009), suggest that simulation could also be effective for accident analysis. By using information from simulated exercises, processes of interaction may emerge that are difficult to elicit in post-accident investigations. These findings may then be used to inform explanatory models of an adverse event.

As demonstrated above, several current researchers view creativity and improvisation as key features in emergency response training. At the same time, making it possible for users to display these traits is a serious challenge, and the same is true for simulating the effects of improvisation (Mendoça & Friedrich, 2004). The following sections will describe a number of examples where simulation and virtual worlds are used for ERS purposes.

**Simulation and virtual worlds**

RimSim is a simulation environment, including a tool for decision support, developed by Campbell, Huseyn, Furness, Weghorst and Zabinsky (2008). This project is primarily directed at first responders and aims to facilitate both planning and training. Because the system allows responders to familiarize themselves with different roles involved in emergency response, these researchers believe that its use may reinforce situation awareness and distributed cognition. Components exist to support social cognition (realistic communications) and dynamic visualization (shared artefacts, e.g. shared geospatial visualization). Decision making is supported through algorithms that can make suggestions for resource assignment. A similar project is described by Taber (2008). The SIMergency Project allows emergency responders to train for collaboration around incident management at a fire scene. Participants are supported with collaborative software and work together in decision making. Here it is stressed that training for emergency response must incorporate social elements, because of the impact of factors like trust and mutual understandings in actual emergency management.

It may be questioned how much of training in virtual worlds actually transfers to real-life situations, an issue which was investigated in a military context by Kylesten and Nählinder (2011). These researchers used micro-world simulation technology (NEWFIRE) to determine whether simulation training had an effect on team decision-making in regular command-and-control exercises. Differences were indeed found between the experimental and the control group. The former were more successful in their tasks, displayed a greater winner mentality and pioneering attitude, and was more active in the gathering of information.
Kylesten and Nahlinder make the interpretation that the experimental group became more adept at working systematically and thinking about causal connections, features that affected their work procedures. Perhaps, it is suggested, micro-world training equipped these persons with mental schemas for the task at hand. This may have produced a more formal way of thinking, evident in a larger simplicity of work (i.e. more routine-oriented and systematic), something that seems to go against theories on NDM and RPD.

Yao, Turoff and Chumer (2010) note that face-to-face interaction holds numerous advantages over other communication media. Meeting face-to-face makes it possible to transfer a rich variety of cues, it allows for instant feedback, and distractions are less detrimental. Yao et al. cite previous research where it has been demonstrated that teams engaged in face-to-face collaboration consistently outperform virtual teams. Still, virtual teams are often necessary because of practical circumstances. These researchers present a Group Support System called Collario, which is primarily meant to aid in the making of emergency plans. Although this system is a work in progress, several useful concepts and guidelines for design of virtual collaborative systems are presented. In the future, these researchers aim to study the effects of factors like synchronous/asynchronous collaboration, group size, group composition and different group dynamics in this context.

Hiltz, Ocker and Plotnick (2011) point out that while teams working together in a shared context can draw many benefits from face-to-face collaboration, this does not always hold true for between-team collaboration. In order to support cohesiveness even among distributed teams, Hiltz et al. suggest the use of online collaborative learning in Partially Distributed Teams. This training takes the form of Asynchronous Learning Networks, virtual classrooms where students can interact around team projects without demands for exact synchronization of work. Positive results are reported from extensive experiments and Hiltz et al. suggest that similar methods could be used to bring emergency response teams from different agencies closer together. Asynchronous online collaboration is also promoted by Taber (2008), who mentions that these types of activities give students more time to think, and that they may therefore be better suited for persons who find it hard to speak up in a classroom environment.

A number of researchers wish to strike a middle path between virtual world training and real-life exercises. For example, Taber (2008) stresses that online collaboration often makes it difficult to establish relationships and trust between participants, much because of a lack of face-to-face interaction. On the other hand, some students may find it easier to be active in online training and interaction. Taber suggests a middle ground, drawing on positive traits found in both varieties. Kanno and Furuta (2006) developed a simulator for the assessment of emergency response systems, which allows for inter-organizational communication and coordination. Results from their experiments similarly give that while simulations are efficient for assessing peak workload of operators, unavoidable simplifications make it necessary to combine virtual world training with more hands-on exercises.

**Other training activities**

The chapter prerequisites for coordination dealt partly with planning for emergency response, and it was mentioned that some researchers wish to move focus away from the
actual plans produced. Instead, collaborative planning activities themselves may be what
really cater for coordination between teams and organizations in multi-agency operations
(Eriksson, 2009). Eriksson observed this when studying the aftermath of Hurricane Gudrun in
Sweden and states that at any rate, plans without accompanying training will be of little value.
This theme is adopted by Lage, Borges, Canós and Vivacqua (2011), who have studied
collaborative scenario creation as a means of supporting plan generation and general
coordination. Scenarios are meant to describe people and their activities in terms of situational
attributes, site descriptions and environmental circumstances. These researchers argue that
scenarios promote communication among stakeholders, making a variety of actors involved in
design processes. For example, it will be natural to involve sharp-end operators, because their
knowledge about contextual factors will contribute to making scenarios realistic. What is
developed during such sessions may also naturally be used for simulation purposes, apart
from its value for planning. Technology for these purposes is researched by Aedo, Bañuls,
Canós, Diaz and Hiltz (2011). Aedo et al. state that the planning process makes capacities and
resources clear for system operators. It also allows professional emergency responders to
identify their partners, forming valuable relationships and working up shared perceptions.
Emergency plans should, according to them, be regarded as evolving resources rather than
strict regulations. These researchers promote user interfaces that are multimodal and touch-
less to promote natural interaction and collaboration. Equally important is the way scenarios
and other information are spread throughout an organization. Jenvald, Morin and Kincaid
(2001) describe requirements for a network aimed at this task. They have observed that plans
based of previous experiences are vital for efficient learning, together with the communication
of other experiences, like how to use new equipment. Policy makers, commanders, planners
and first responders should be able to involve themselves actively in information sharing,
planning and design of policies and instructions. Jenvald et al. envision a web-based interface
for this purpose.

Learning typically takes place prior to actual emergency response, while hopefully
incorporating lessons learned from previous events. Moynihan (2009), however, argues that
many valuable opportunities for learning may be found during a crisis. This type of learning is
made more difficult by the cognitive rigidity produced by stress, and by the obvious
limitations to using a trial-and-error approach. Instead, an emergency response system should
be designed to support situation understanding and learning, for example through timely
delivery of information and by making Standard Operating Procedures (SOP) accessible.
Operators should be actively involved in reshaping SOPs. These may then serve as an
organizational memory of past events. The subject of intra-crisis learning is, according to
Moynihan, an understudied topic.

Only a few articles have been found during preparations for this review with regard to
training directed at specific actors. The need for this would certainly be an implication of the
wide-spread call for more clearly designed work-roles in emergency response (e.g. Bergström,
touches on this, referring to research on team leader training. Training these
persons to give team members continuous situational updates improved both individual tasks
and teamwork. This coordinative role could be argued to resemble what has been described as
boundary spanners or liaison officers in previous chapters (e.g. by Uhr & Johansson, 2007),
and may be an example of a new type of leadership, something that is mentioned by Landgren (2005). It would likely be possible to find other ways of supporting commanding roles through training activities. Reuter, Pipek and Müller (2009) mention a number of more direct training activities which can be used to prepare responders mentally for their tasks. These may include different forms of stress reduction such as relaxation techniques and desensitization.

**Systems modelling and evaluation**

If an emergency response system is to be designed that provides real support for communication and coordination, then designers must take off from a truthful model of involved organizations and their tasks. Consequently, researchers and designers must immerse themselves in the practicalities of everyday work, because as Nemeth, Wears, Patel, Rosen and Cook (2011) state, the gap between work as imagined and work as it is actually performed will largely determine the usability of designed artefacts.

**Systems modelling**

Several methods for both modeling and evaluation have emerged from the field of Cognitive Systems Engineering. These have proven valuable because of their ability to reflect the complexity and coupling of modern sociotechnical systems.

Nemeth et al. (2011) performed studies in the healthcare domain, looking for issues that could be countered with the use of information and communications technology. To do this, these researchers utilized a broad range of qualitative techniques for data retrieval. *Observation* at the place of work provided contextual information. *Informal interviews* were used to get a sense of the work team”s history and to gather preferences from individuals. *Artefact Analysis* could show how objects and systems in the work environment were used to store, process and communicate information. *Critical Incident Studies* is an introspective tool where participants recount the handling of past events. *Critical Decision Method* (CDM) is one example of such a method. To reveal the cognitive demands of certain tasks, *Cognitive Task Analysis* (CTA) may be used. CTA can include methods to study task complexity, situation awareness, decision making and planning. Results produced may then be used to assess the design of technological artefacts, for example concerning information requirements or cognitive offload. Borges, Engelbrecht and Vivacqua (2011) used a *Twenty Questions* technique in combination with scenarios and *storytelling* by participants under the heading of CTA when implementing a digital tabletop for emergency management use.

After data had been collected, Nemeth et al. (2011) used a number of other methods to construct a model of the observed domain. *Work Domain Analysis* is a constraint-based method and was used to identify goals and associated constraints in work. Following this, *Process Tracing* revealed patterns of care activity, all the while focusing on cognitive strategies of the observed professionals. Results consisted of flow maps describing work at an emergency department, where risks and possible areas of improvement could be identified in a convenient manner.

A development of CTA exists in *Cognitive Work Analysis* (CWA), used by Wickler, Hansberger, Potter and Tate (2011) to develop a virtual collaboration environment. In many ways, this method has a wider scope. It is a constraint-based method, used to uncover both technical and organizational relationships that must function if work is to run smoothly. In
accordance with CSEs fundamental concept of uncertainty in complex systems, CWA is not normative, in other words, it should not be used to try to describe what workers should ideally do. Instead it attempts to capture the ability of operators to adapt, describing what they could do to achieve their goals. This is accomplished through an analysis of contextual complexity, revealing the contextual constraints that apply to work. Norros and Salo (2009) criticize both CWA and other above mentioned methods for what they see as an insensitivity to cultural traits in work environments. In the words of these researchers, a system’s history creates dispositions, or habits, to act in certain ways. To reach an understanding of these habits, both tools and technology must be analysed with regard to instrumental and psychological functions, as well as to their role as communication media.

Another strand of research around system and work modelling is Activity Theory (AT), which is put into an emergency management context by Allen, Mishra and Pearman (2011). Researchers using AT try to relate human activities to their social background and do not regard humans as system components. Here, intentional human activities, goal-directed actions, constitute the focus of study. Tools may mediate activities and impact human cognition. During activities, tools will be created and transformed, which makes them important cultural objects for communication and social knowledge. Activities can be linked into an activity system, making up a system model of goal-directed behaviour.

A third group of researchers concentrate on networks and network theory in their modelling and discussion of emergency management systems. For example, Uhr and Johansson (2007) discuss the response to Swedish hurricane Gudrun and a large-scale chemical spill in the Swedish town of Helsingborg, both events taking place in 2005. These researchers wish to emphasize interactions among agents in a system and hold this as the key to understanding problems in response coordination. To describe relations in the network, Uhr and Johansson use the labels contact, important contact, friendship and formal relation. Data for models was collected using web-based questionnaires and interviews. The importance of understanding social context in modelling is also stressed by Ödlund (2010), especially when talking about non-hierarchical organizations.

**Systems evaluation**

Many of the above mentioned techniques for modelling systems also lend themselves to assessment. For example, if issues exist in human-technology interaction or communication, different forms of task analysis or work analysis will likely be able to reveal these. But it may not always be practical to remodel the system at hand for every new evaluation, and the validity of a model will probably diminish with time. Dugdale, Darcy and Pavard (2006) hold that few tools actually exist for analysing the robustness of a system, apart from common qualitative methods. On the other hand, there is also a risk of overlooking organizational, cognitive or social aspects of system functioning in the search for factors that are easy to measure (Janssen, JinKyu, Bharosa & Cresswell, 2010). Janssen et al. stress that researchers must have a deep understanding of system interactions and complexity for an evaluation to be truthful, something that makes a case for richly descriptive, ethnographic methods.

Abrahamsson, Hassel and Tehler (2010) describe a system-oriented framework for the evaluation of emergency response. These researchers mention how difficult it may be to
foresee the performance of any socio-technical system, because of the impact of social relations and interactions. The nature and functioning of such relations must be understood in any system evaluation. For this purpose, inspiration could be gathered from the field of accident analysis, where several methods exist that take complexity and coupling into account. One example could be the Functional Resonance Analysis Method (FRAM) (Hollnagel, 2004). Furthermore, analyses will always be susceptible to psychological factors such as different cognitive biases. Analysts must strive to become aware of such biases in their course of work, or in reports gathered from system operators. Abrahamsson et al. (2010) suggest a basic analytical structure consisting of system elements, relations and boundaries between system and environment. Their analytical process begins with the mapping of actors, tasks and objectives, along with performance measures for tasks. This is followed by an analysis of system interdependencies and agent requirements such as resources, infrastructures and performance of other agents. After this mapping, a system dynamics model may be constructed and subjected to different scenarios, revealing possible issues.

Stojmenovic, Dudek, Lindgaard, Noonan, Sen and Tsuji (2011) utilized a range of techniques to assess user requirements for a disaster response system, including Social Network Analysis, Content Analysis, Latent Inductive Content Analysis and Observation Analysis. Although the different methods generated different types of results, observation analysis was most productive overall. It was not only the easiest one to use, but also identified the most user requirements. In conclusion, given that all methods still contributed to the sum of experiences, Stojmenovic et al. argue for using a combination of assessment techniques.

Apart from qualitative analysis, some attempts exist to use quantitative methods for ERS evaluation. Reliability Analysis is a common method for system evaluation within many technological industries, and some researchers also argue for its use in the emergency response domain. This is discussed by Jackson, Faith and Willis (2011), who stress the impact on a system’s reliability by factors like recurring training, maintenance and updating of plans. Reliability is concerned with the likelihood that a system for emergency response will be able to perform as intended in a variety of future incidents. Jackson et al. combine experiences from probabilistic risk analysis, theory of High Reliability Organizations and Perrow’s Normal Accident Theory using Failure Mode Effects and Criticality Analysis (FMECA). This method is normally used in technological contexts and starts with the definition and mapping of a system. This is followed by the identification of failure modes, that is, different ways in which system performance could break down, and their respective probabilities, severities and effects. Being able to present hard numbers around possible future crises would, in the opinion of Jackson et al. (2011), make it easier to argue for investments in the ERS domain. Failure modes could also be used to assess the results of exercises, when these are used for system evaluation, and make comparisons with actual incidents.

A number of more direct measures that could be used for system evaluation can also be found in the literature. For example, Salasnyk and Lee (2006) mention the factors detection time, preparation time, response travel time, travel distance, response time and incident duration and clearance time. Mendoza and Fiedrich (2004) add a number of other measures, such as human and property loss, environmental aspects and costs. However, these researchers also mention how difficult it often is to compare incident outcomes over time, given the variable nature of contextual factors in emergency response.
Design guidelines

With previous chapters as a background, certain requirements for the design of emergency response systems should now begin to emerge. These will be presented under the subcategories requirements and Methods in design work.

Some researchers (e.g. Janssen, JinKyu, Bharosa & Cresswell, 2010) stress that ERS design must always be firmly rooted in contextual understanding, acknowledging for operational uncertainty. Janssen et al. state that while systems are often designed according to probable scenarios, incorporating detailed routines, such systems may become too rigid when faced with variability. Another central issue mentioned by these researchers is that system development is often technology-driven. That is, developers often give priority to trying out new technological solutions, all the while ignoring user requirements and system interdependencies. Because of this, it has often been difficult to establish that emergency response actually benefits from the introduction of new technology (Norros, Liinasuo & Hutton, 2011). In the words of Norros et al., designers must concentrate on the joint functioning of the socio-technical system. Failing to apply a systems view in design may also have other consequences.

Applying a systems view on design not only applies to internal and external interaction, but may also relate to a system’s objectives. For example, Van de Walle and Turoff (2008) argue that an emergency response system must allow for the management of a broad range of incidents. If some tools exist solely for large-scale events and are not used on a daily basis, chances are that they will be forgotten in the case of a larger crisis. A similar point is made by Woltjer, Lindgren and Smith (2006). These researchers hold that artefacts used during training should mirror those used in sharp situations, which means that the design of training environments and design of actual work tools must be closely linked.

Norros et al. (2011) also point to a related and equally central issue in system design, referred to as the task-artefact cycle. The reasoning behind this concept is that designers often misjudge the implications of technological system changes. When new technology is introduced, work in a system inevitably changes, thereby undermining the assumptions on which the original innovation was based. New user demands will emerge, and naturally, fulfilling them will create further issues that will have to be resolved, in fact rebooting the design cycle. This means that system design has to be an iterative process, where designers are constantly assessing the contextual effects of system changes. Issues concerned with the task-artefact cycle could explain the results of Granlund and Granlund (2011). They conducted experiments showing that the introduction of GPS technology in crisis response actually hampered performance under some circumstances, as opposed to what was expected. This happened because work and assumptions of participants had changed in an unexpected manner.

Requirements

It has previously been mentioned that system development is often technology-driven and that a balance must be found between user needs and technological innovations. Similarly, Norros and Salo (2009) note, designers must not become carried away in their will to make broad revisions. Business stakeholders often push for radical changes, but system stability often calls for a more moderate approach, where new features build on existing
structures. Again it is important to take the overall system into consideration, because profound local changes may make it more difficult to interact with other teams, agencies or organizations. Norros and Salo particularly stress the importance of user involvement in all stages of system development. Massive involvement of end users will make it much easier for researchers and designers to understand contextual factors, something that is vital for system usability. In their 2009 article, Norros and Salo present a framework for joint system design, where the weight is put on contextual understanding and user needs.

Jungert, Hallberg and Hunstad (2006) present another framework for ERS development, stemming from research on command and control (C2) systems. Four requirements are described as central and mirror the above chapter on response system features. A system should support communication and information exchange, gathering and fusion of disparate data, collaborative decision-making and coordination of activities and resources. Similar to the reasoning of van De Walle and Turoff (2008), these researchers also argue that systems should be designed to cover both everyday and large-scale crises. This will make agents proficient in the use of supporting artefacts. Furthermore, it will also maintain intra- and inter-organizational interaction during periods of comparatively low activity. All agents within the systems should be supported in maintaining a Common Operational Picture, something that calls for efficient dissemination and directing of information. Making sure that all system participants are properly informed will also cater for creativity in the work process. Jungert et al. (2006) provide an extensive list of functions that any ERS must incorporate. This includes cooperation between organizations and agencies, collection and availability of information according to user needs, balancing information availability against integrity, tools for manipulation of sprawling data collections, decision support, communication of decisions and interaction with the public. To grant these features and to support flexibility, Jungert et al. argue that organizations must be designed in a network fashion. Human factors issues must also be considered early in development, because features like human-system interaction and decision support may be difficult to incorporate at later stages. Further, Jungert et al. go on to describe a service-based architecture for the development of C2 systems.

Another rich framework for ERS design is presented by Chen, Sharman, Rao and Upadhyaya (2007), mirroring most sections of the above chapter on necessary ERS features. They base their work on research by Turoff and highlight a large number of typical causes for delays in emergency response, a detailed account which will only be partly related here. At early stages of response, work may be delayed by lacking situation awareness caused by limited or contradictory information, leading to an underestimation of the extent of the incident. This calls for decision support functions as part of an information system. After dispatch, work may be delayed in the phase of preparation, that is, when suiting up, collecting the right equipment and so on. Chen et al. argue that such issues can be countered with training initiatives. On the way to the scene and once arrived, work may be hampered by lacking communication, with problems in information gathering and decision making. Situation awareness must once again be properly supported through interactive publishing, managing and distribution of information. This means integrating many types of information from various sources, using several types of media and many different means of distribution. This process also calls for shared standards in communication and data formats. SA facilitates a number of important activities such as risk assessment, resource management and planning.
It will also help establish coordination between teams and organizations at the scene, as well as the proper management of resources. For this to be possible, agencies must also share interests, goals and visions, a problem which is often more pronounced in large-scale response efforts. Coordination will stem from joint training and from a COP, produced by a well-functioning information system which does not create barriers between organizations. During a large-scale crisis, a strategic planning module must oversee individual response efforts and inform responders, so as to maintain overall objectives and avoid conflicts. An important tool for this activity is performance monitoring, which can be realized through tracking systems, visualization tools and tools for information analysis.

More detailed requirements for an Emergency Management System have been created by Stojmenovic, Dudek, Lindgaard, Noonan, Sen and Tsuji (2011), who concentrate on the needs of Incident Command. An information system should assist commanders in the distribution of information, so that the right information reaches the right persons at the right time. At the command post, structures should exist that allow for both collaborative, small-group and private work. Furthermore, command post operators must have tools for the creation, updating and sharing of action plans. Similar to Chen et al. (2007), Stojmenovic et al. (2011) also stress the importance of effortless generation, management and distribution of information. In relation to first responders, commanders should have the ability to track equipment and personnel, define and share work roles, and manage authority.

Efficient and effective emergency response depends on communication and organizational coordination. This means that information technology must be designed to provide proper support for decision-making and action (Comfort, Dunn, Johnson, Skertich & Zagorecki, 2004). Consequently, a heavy emphasis must be put on the design of artefacts. These must be transparent enough to create a joint relationship between people and technology. Rather than replacing humans, artefacts should amplify human skills (Woltjer, Lindgren & Smith, 2006). Affordances in artefacts also depend on the relation between actors and environment, which means that artefacts must be adaptable to situational circumstances (Norros & Salo, 2009). This adaptability may, for example, mean that all information is not simply shared between all actors, but that it is filtered according to individual or team needs (Bergström, Dahlström, Henriqson & Dekker, 2010). COPE Deliverable D2.3 (Norros, Liinasuo, Savioja & Aaltonen, 2011) describes the human factors contribution to a large Finnish project on COP and brings up a number of artefacts deemed central for the forming of a common operational picture. A terminal for actor participation should be available. In tests, this allowed all personnel to contribute to the forming of a COP and made it easier for commanders to interpret the situation at hand. New sensor technology was widely acclaimed among responders, e.g. sensors to probe the spread of dangerous chemicals combined with means for visualization, and thermal cameras used during smoke diving. Built-in processes for semantic structuring of information did not receive many comments from responders, but were nevertheless deemed important for information filtering. Finally, a gateway and WLAN for the sharing of information was very positively received by its users, facilitating commander-responder communication and allowing for efficient logging of information. Norros et al. view techniques for information filtering (e.g. semantic structuring) as a very important area of future research. Another research priority should be the development of
integrated systems for communication, where many types of media can be used and where first responders can be active contributors.

**Methods in design work**

Given the dominance of systems-oriented, context-sensitive theory within the current ERS discourse, it should not come as a surprise that most research included in this review gravitates toward user-centered design and ethnographic methods. Consequently, several of the methods described in the chapter “Systems modeling and Evaluation” could also be included here, and will not be described again.

Taber (2008) states that design should be rooted in an understanding of human or societal needs, not driven by strictly technological interests. Using participatory methods of design will not only improve the product itself but will also improve acceptance of new system features. One typical example is a study by Norros, Colford, Hutton, Liinasuo, Grommes and Savioja (2009), dealing with the development of information support systems for emergency response. Design was based on a usage-driven model by Crandall, starting with the creation of domain understanding, where cognitive work challenges were mapped using the Critical Decision Method. This was followed by analysis and representation of data, using a functional modeling approach. These models became the departure point for application design, ending in user-centered activities of product evaluation. Norros and Salo (2009) give a more detailed account of design principles for joint systems, touching on core-task analysis, general ethnography, use of scenarios, mapping of user requirements and analysis of features like coordination, resilience and affordances.

Hollnagel (2005) presents a modified version of CTA called *Cognitive Task Design* (CTD). CTD acknowledges that any changes to a system, for example the introduction of a new technological artefact, will change how work is carried out, conceived and organized. This has previously been referred to as the task-artefact cycle. Because of that, designers must not only direct their attention at the individual operator and his/her supporting technology, but also at the consequences new technology has for the larger system.
Areas of future research

This literature review has produced results under the headings System architecture, Coordination, Information and Communication, Handling uncertainty, Training and learning, Systems modelling and evaluation and Design guidelines. Furthermore, each of these sections has hinted to possible areas of further research. This final chapter will revisit these topics and provide an overview, which may be used to guide the development of future CARER activities.

Cognitive science topics

Results include an exploration of cognitive concepts that are often used to frame ERS studies. They may also be used to elicit requirements during evaluation, design and construction. However, different strands of research appear to prefer different vocabularies, and while all concepts have proven productive in their respective contexts, it may be interesting to perform a deeper review of their differences, similarities and possible conflicts. What is the relation between concepts like Shared Situation Awareness, Collective Mindfulness, Shared Mental Models, Common Ground, Sensemaking and Common Operational Picture? Does their distinction have any profound effects on the interpretation of results in ERS research? Furthermore, how does Naturalistic Decision Making, for example Recognition Primed Decision relate to cultural factors or social dynamics behind decision making? Some researchers, like Njá and Rake (2009), see this as a major drawback of models focused on individual cognition. RPD has also been compared to the typical behavioural patterns provoked by stress. Is it fair to view RPD as an un-intellectual, instinctive mechanism? How does this theory relate to ideas of increased awareness in work and decision making, such as Mindfulness? And what could this rather private process of recognition-primed acting bring about in relation to communication and coordination with other professionals at the work site? Even though some of the above-mentioned concepts have a long history within the research community, new implications could come from the current research interest in collaborative processes and social contexts.

Handling uncertainty

Handling uncertainty constitutes an overarching theme in ERS research. In all sections of this chapter one could begin with the question of how to enable a system to adapt in the face of unexpected situations, or better yet, how to enable anticipation in a dynamic environment. As noted earlier, chances for prediction are often slim in emergency response. Each of the headings coordination, communication, information handling and training can be explored from this point of view. What creates resilience in an ERS? And will this feature also improve a system’s ability to tackle both small and large emergencies? There are some particular themes to investigate. For example, Grote, Weichbrodt, Günter, Zala-Mező and Künzle (2009) suggest flexible routines as a middle ground between adaptability and stability, but the realisation of this idea must be studied further. Another are of interest may be risk assessment during emergency response and different ways of supporting decision making. Rankin, Dahlbäck and Lundgren (in press) suggest that the ability for improvisation is vital, and future research may explore how this ability can be created. However, all concepts around flexibility also have to tackle issues of misunderstandings and team/organization isolation,
difficult challenges in their own right. Further, as shown, there is a distinct feeling of uncertainty amongst the different actors at the incident site. Is it possible to increase confidence in intervening actors, and how may the social identity made salient increase or decrease the feeling of uncertainty?

**System architectures**

Research on system architectures for emergency response is currently a very active field, because of the debate between those who argue for hierarchical structures and those who see larger benefits in organizational networks. Some researchers (e.g. Windischer, Grote, Mathier, Meunier Martins & Glardon, 2009) suggest that networks are more suitable for situations of high uncertainty, while hierarchies are better for predictable scenarios. On the other hand, while large-scale emergency response is often described in terms of dynamics and unpredictability, the same circumstances have been argued to hold for everyday emergency response (Nemeth, Wears, Patel, Rosen and Cook, 2011), and network structures do seem to be more compatible with cognitive systems theory. Future research should explore these questions. Can network structures be used effectively in both teams, organizations and in organizational collaboration? Can they be applied both for everyday emergency work and for large-scale activities? Can different architectures be used in different contexts? And could that be done without losing system stability and training benefits? Or could a combination be implemented, as suggested by Janssen, JinKyu, Bharosa and Cresswell (2010)? From a social point of view, it may also be interesting to think about what a network architecture for emergency response would mean for cultural cohesion and shared understandings. According to some researchers (e.g. Berlin & Carlström, 2011), Swedish agencies are already both technologically and culturally isolated. It could be speculated that more autonomous teams would form cultures of their own, decreasing both intra- and inter-organizational affinity. Other issues may arise from vague authority and lacking accountability (Ödlund, 2010). These are all questions that could be pursued in future studies. Using CSE concepts to model, evaluate and design systems for emergency response is a general future challenge. Norros, Colford, Hutton, Liinasuo, Grommes and Savioja (2009) argue for a function-based modeling approach, and it may for example be interesting to test the FRAM (Hollnagel, 2004) in an emergency response context. There is a general need for creative and context-sensitive methods for ERS evaluation.

Finally, if network structures were to be preferred, this would likely call for studies producing a whole new generation of supporting artefacts and systems, because user requirements would likely be very different from before.

**Coordination**

Berlin and Carlström (2011) have shown that when Swedish emergency responders are pressed, they revert to within-agency established modes of work. Coordination is typically regarded as a key feature for effective emergency response, and the results of Berlin and Carlström demonstrate that coordination between agencies cannot simply be a loose ambition. On the other hands, some researchers hold a different opinion. According to Danielsson, Johansson and Eliasson (2010), responders from different agencies often have no reason to collaborate. Could coordination be carried out to differing extents depending on the situation?
Or would inter-organizational relations suffer if they are not continuously reinforced? Could valuable opportunities for learning about response coordination be lost? According to Grote, Weichbrodt, Günter, Zala-Mező and Künzle (2009), coordination stems from shared experiences. These are questions that could be pursued in future studies. In a Swedish context, technological implications for coordination could be investigated, for example the effects on coordination possibilities of the new system for communication (RAKEL). Furthermore, do Swedish emergency responders from different agencies interact online or in real life, outside of response activities? Do they join in the creation of procedures, support systems, training and exercises? How could joint command be supported, and in what situations should it be encouraged? It may be interesting to approach this subject from a cultural point of view. Given that shared understandings and trust are regarded as important for coordination and outcomes, what could produce shared cultural traits between agencies?

Research on other facets of emergency response may have great consequences for coordination, both within teams and between larger system constituents. For example, because flexibility has appeared as a prerequisite for emergency response, some researchers argue that responders should be able to assume different work roles (Rankin, Dahlbäck & Lundberg, in press). If this process is to be coordinated by a commander, then this task should be investigated. If it is to be a spontaneous process, then it may be important to study how this would affect situation awareness of responders, in other words, their knowledge of the activities and goals of others. Furthermore, to what extent can work roles be flexible without undermining professionalism? And could some type of role exchange even be envisioned between organizations, perhaps even through engaging the public? Continuing, new organizational structures (such as networks) will likely call for new work roles. For example, what does work in net-centric teams and organizations mean for the roles of Incident Commanders or Team Leaders? And how could the role of Boundary Spanners (i.e. persons who aid in coordination between teams and organizations) be designed? Could they fill the function of “information orchestration” (Bharosa, Janssen & Tan, 2011) or should this be a task for commanders?

Some areas connected to coordination have been difficult to cover in this literature review. For example, no research has been found describing interaction between emergency dispatchers and first responders with regard to information sharing, situation awareness, COP or related concepts. Neither have any articles been found describing interaction between commanders and first responders from a cognitive systems perspective, nor their respective information needs during different phases of emergency response. It is quite possible that such studies exist, but the focus in most research lies on large-scale events. Everyday emergency response could likely provide a setting for interesting observational studies on coordination.

Technological support for coordination in an ERS is an open field of study. Some examples exist in the literature, but there is a great need for solutions enabling shared situation awareness, joint planning and decision making, resource allocation and manning. It is the aim of network-oriented researchers to involve both commanders and sharp-end operators in these activities, but doing so will naturally place high demands on technological artefacts. It may also be asked whether tools for decision or planning support are applicable in everyday emergency response, given its narrow time-frames and the fact that a command
post/center does not always exist. The general issue of scalability for tools and technological support systems should be made a research priority. As noted in preceding chapters there are many advantages to a unified system, applicable to both smaller and larger emergencies (Woldtje, Lindgren & Smith, 2006). In relation to artefacts for coordination support, more specific areas of interest could be digital tablettops and the general design of collaboration-enabling command post environments (both permanent and temporary).

Finally, very little research has been found concerning the collaboration between emergency responders and the general public. Bystanders are a given feature of both small and large emergencies, making up an untapped resource for first responders. In the chapter on information and communication, some comments were made around WreckWatch, a smartphone application for accident detection and information handling (White, Thompson, Turner, Dougherty & Schmidt, 2011), and the use of mobile cellular video calls (Bolle, Hasvold & Henriksen, 2011). These two projects touch on the subject of bystander participation, but there ought to be room for many more.

**Information and communication**

Information and communication technology (ICT) has a central role in present-day ERS research, because ICT enables important processes of collaborative coordination, planning, decision making and learning. An important topic is general methods for information sharing within and outside the ERS. There is a need for structures and technology facilitating information exchange between command and first responders, between teams, between agencies at different levels, and between responders and the general public. As noted above, modern technology can provide first responders with a wealth of information, but this is not without its complications. Future research will have to handle the issue of balancing information availability against both information overload and information security. This will include the study of methods for information filtering, directing and timing. Some research examples exist, for example timing information delivery to different response phases (Cimiano, Hidders & De Lignie, 2011), but there is much more room for creativity here. A general challenge for new information technology will be to support situation awareness, shared among responders, commanders and the general public. For example, how could first responders be involved in information handling given the limitations of their work conditions? And how could the entire system be made aware of updated plans or procedures during response, without risking information overload? And how could ICT contribute to the building of relationships and trust between agents and agencies?

General information sharing also means that the system must accept a broad range of media and have the capability of fusing together disparate data into one unified picture. Furthermore, there is a clear need of research on how first responder work would be affected by adding these types of resources. Berlin and Carlström (2011) have demonstrated that several information barriers exist in the Swedish emergency response context. Could technologies be used to bring together information from vastly different sources (different radio networks, telephone communications, instant messages, photos, video etc.) or does this call for an entirely new system? The topic of information wealth also relates to the study of sensor technology. Some researchers (e.g. Norros, Liinasuo & Hutton, 2011) report very positive results in this context, and modern technology allows for innovative solutions, for
example flying, self-arranging sensors (Purohit, Sun, Mokaya & Zhang, 2011) or the use of smartphones for accident detection (White, Thompson, Turner, Dougherty & Schmidt, 2011). Presently, only creativity appears to limit the possibilities within this field of study. Using media like pictures, videos and audio recordings also increases data traffic, which is why research on ad hoc networks, MESH networks etcetera will become more and more interesting. Network technology of this type provides resilience in the face of infrastructural damage, or in areas of low network coverage. Another related topic is system scalability. Could a system be designed to cover needs for both everyday and large-scale emergency handling? There are many benefits to using the same artefacts and organizational structures routinely (Woltjer, Lindgren & Smith, 2006), for example for learning, but this may also constitute a great challenge for system and artefact designers.

Closer to first responders, other modes of communication could be investigated. For example, many benefits are associated with face-to-face interaction, but circumstances do not always allow for this. Are there some specific features in face-to-face communication that could be transferred to online communication, or are there other features of collocation that could be replicated online? Some research exists on the use of virtual collaboration environments and other Web 2.0 technology for training (e.g. Wickler, Hansberger, Potter & Tate, 2011), but there may also be a use for similar solutions during the response phase. It is also possible that other solutions could compensate for a lack of collocation. For example, Johansson and Persson (2009) have noted that mediated communication is made easier if a relation exists. Perhaps other inter-agency activities prior to actual work could fill this gap.

Training and learning

Training and learning are normally considered as pre/post-emergency activities. However, Moynihan (2009) suggests that learning during an event is an understudied topic. There is a great need of research exploring methods, structures and tools for making the most of the work experiences of first responders. Naturally, richer information from actual emergencies may also contribute to the quality of normal training activities. Possible routes could be better functions for logging, or better ways of communicating experiences during work. Logged information can for example be used to inform scenario creation for simulation, and simulation has been suggested as a tool for post-emergency investigations (Latiers & Jacques, 2009).

Certain underpinning concepts for ERS research have emerged in this review. Naturalistic decision making, creativity, improvisation, adaptability, cultures, situation awareness, mindfulness, social identity, self-categorization and coordination could serve as departure points for many strands of research, and this is also true for the study of training and learning. For example, it may be interesting to study to what extent training activities of different Swedish agencies overlap. Is there joint training for both everyday and large-scale emergencies? Do agencies utilize simulation technology to the same extent? Could training be designed to support coordination between agencies in a better way? Are operators from all agencies involved in collaborative creation of scenarios and plans, which are then used for training purposes? And what maximizes the transfer of training experiences to real-life situations? From a social identity perspective; can a joint social identity be achieved in collaborative training involving all agencies? May a shared social identity then emerge at the
incident scene? On a more local level, are operators involved in the design of work roles, and does training cater for the needs of specific actors? Some researchers suggest that training could have effects on basic individual traits. For example,Kylesten and Nahlinder (2011) suggest that micro-world training can introduce a more formal (and superior) way of thinking. This seems to go against theories on naturalistic decision making, and it is a claim that could be scrutinized in future studies. One might ask if it is at all possible to overcome cognitive biases through training, as claimed by Comfort (2007), or whether this is just a matter of mental resource assignment.

Also, may public education and involvement in life support training increase the intervention behaviour at incidents sites amongst bystanders? And, is it possible through training the public to decrease the lack of confidence in lay responder actions from the professional actors, facilitating their tasks by getting an extra pair of hands and eyes?
Summary

Previous chapters have highlighted a number of themes central in the discussion of ERS design, training and practice. Applying cognitive systems theory to the study of emergency response shows the importance of interaction, both within and between responding organizations. This field of research also provides a number of related concepts that can be used to frame central needs in emergency management, such as the prerequisites for control, situation awareness, decision making and learning. The distributed and coupled nature of these features in interaction puts a heavy emphasis on coordination, communication, learning and adaptability in response efforts.

The theoretical point of departure within this field may have profound effects on the fundamental structures of emergency response systems. This was claim was investigated under the heading System architecture. There are differing opinions within the research community to whether a hierarchical or a network organizational structure should be preferred, or whether it could be possible to find a working combination between the two.

A Joint Cognitive System approaches control through processes of coordination (Bergström, Dahlström, Henrikson & Dekker, 2010), made harder by the temporary work groups of multi-agency emergency response (Comfort, 2007). Coordination may cover integration and timing of activities, allocation of resources, and also dynamic allocation of authority depending on situational demands (van de Walle & Turoff, 2008). Information-related issues, strongly connected to coordination, have been identified as key problems for workers in public safety networks (Bharosa, Janssen & Tan, 2011). Information is used to improve situation awareness and support distributed cognition, which are in turn prerequisites for decision-making, planning and adaptability (Schraagen & van de Ven, 2011). Well-functioning cognitive artefacts are a general prerequisite for coordination and communication. Technological support for coordination is largely a matter of information sharing and management (Salmon, Stanton, Jenkins & Walker 2011), covering information gathering, integration, visualization and dissemination. A number of related technologies have been presented, such as wireless mesh networks, web 2.0 technologies, virtual worlds, peer-to-peer communication platforms, on-line communication with the general public, video conferencing, virtual whiteboards, command centre environments, digital tabletops, innovative sensor technology and networks, tracking devices, handheld devices, knowledge management systems, decision support, check-lists, geographic information systems, communication standards, phase-dependent information distribution, mobile phones and proactive analysis programs (Bertsch, Geldermann, Rentz & Raskob, 2006; Woltjer, Lindgren & Smith, 2006; Chen, Sharman, Rao & Upadhyaya, 2007; Turoff & Van de Walle, 2008; Militello, Patterson, Bowman & Wears, 2007; Drury, Klein, Liu, Moon & Pfaff, 2011; Wickler, Hansberger, Potter & Tate, 2011). The availability of modern multi-media technology should be exploited, although bandwidth-heavy media must be implemented with regard to network limitations (Lass, Regli, Kaplan, Mitkus & Sim, 2008). Relevant information must be collected, analysed and supplied to the right actors at the right time (Stojmenovic, Dudek, Lindgaard, Noonan, Sen & Tsuji, 2011). Today, information can be provided in abundance, and information overload is a serious issue in this context (Woods & Branlat, 2010).
An incident site is a social context where professional organizations as well as bystanders interact. From this point of view the SIT and SCT perspectives (Levine, Cassidy, Brazier & Reicher, 2002) may be of use in making the collaboration more effective and thereby also affecting the emergency response. Bystanders are a potential resource for first responders, something that could be explored further (Danielsson, Johansson & Eliasson, 2010). Issues connected to social context also include social relations between responding organizations (Berlin & Carlström, 2011). Furthermore, the literature gives that coordination between agencies is often inhibited by technological barriers. Systems should be designed to allow for effortless information distribution (e.g. TETRA networks) and increase awareness of the activities of other teams (Latiers & Jacques, 2009; McMaster & Baber, 2011). Naturalistic features in communication, such as body language, gestures and face-to-face interaction are important for building inter-organizational relations and promoting trust (Taber, 2008). Coordination of response organizations could likely benefit from realistic joint training, relation building, joint planning (Bergström, Dahlström, Henriqson & Dekker, 2010; Janssen, JinKyu, Bharosa and Cresswell, 2010; Salmon, Stanton, Jenkins & Walker, 2011), boundary spanners (Uhr & Johansson, 2007), and clear definitions, allocations and adaptability of work roles (Van de Walle & Turoff, 2008; Schraagen, Huis in „t Veld & de Koning, 2010; Rankin, Dahlbäck & Lundberg, in press). Documents such as policies, regulations and procedures could be made in to collaborative projects, promoting shared perceptions and realism (Grote, Weichbrodt, Günter, Zala-Mező & Künzle, 2009). At the incident site, joint command centres should serve to bring organizations closer together (Militello, Patterson, Bowman & Wears, 2007).

Emergencies call for rapid response (Landgren, 2005) and emergency response is an activity associated with uncertainty (Comfort, 2007). This means that supporting technological systems have to be flexible and robust, something that could be realized through ad hoc (MESH) networks including self-optimization and satellite technology, use of public data networks and dynamic information hubs (Dugdale, Darcy & Pavard, 2006; Bowman, Graham & Gantt, 2007; Kanchanasut, Tunpan, Awal, Das, Wongsaudsakul & Tsuchimoto, 2007; Oliveira, Sun, Boutry, Gimenez, Pietrabissa & Juros, 2011; Panitzek, Bradler, Mühlhäuser & Schweizer, 2011). Continuing, strict procedures may be too rigid to allow for adaptability in the face of unforeseen events (Grote, Weichbrodt, Günter, Zala-Mező & Künzle, 2009; Chen, Sharman, Rao & Upadhyaya, 2011). Some researchers believe that this could be countered through fostering creativity among responders, perhaps by training mental abilities to cope with uncertainty, or by encouraging improvisation (Mendoça & Friedrich, 2004; Turoff, Hiltz, Plotnick & White, 2008; Voss and Wagner, 2010; Rankin, Dahlbäck & Lundberg, in press). Doing so would demand a high level of realism in training environments. Responders could also be trained to take on different work roles depending on situational needs. System interaction could be improved through joint training involving units that affect each other during actual emergencies (Eriksson, 2009). A more far-reaching goal could be an increased autonomy of work teams with the implementation of de-centralized decision making (Janssen, JinKyu, Bharosa & Cresswell, 2010). However, innovations such as these may introduce new problems, such as weakened organizational cohesion, misunderstandings between units and overlapping activities (McMaster & Baber, 2011). These challenges and many more would have to be met when exploring resilience in emergency response.
As already mentioned, training for emergency response must arm responders with creativity, improvising when procedures give no clues on how to tackle unexpected events. Since system performance depends on well-functioning interaction, it must also be designed to promote coordination, communication, information management and joint decision making (Aedo, Bañuls, Canós, Díaz & Hiltz, 2011). When teams and organizations train together, important relations may form that in turn will improve efficiency in sharp situations (Woltjer, Lindgren & Smith, 2006; Uhr & Johansson, 2007). Micro-world-based training has been demonstrated to improve certain features of within- and between-team interaction (Kylesten & Nählinger, 2011). Scenario-based training and simulations make it possible to train under realistic circumstances without the risks inherent in real-life activities (Turoff, Hiltz, Plotnick & White, 2008; Yao, Turoff & Chumer, 2010). Organizations that have small chances of doing joint real-world training can meet and learn online (Aedo, Bañuls, Canós, Díaz & Hiltz, 2011), for example using gaming technology (Reuter, Pipek & Müller, 2009) or web 2.0 technology in asynchronous learning networks (Taber, 2008; Yao, Turoff & Chumer, 2010; Hiltz, Ocker and Plotnick, 2011). When more and more training is carried out in virtual environments, it becomes increasingly important to involve sharp-end operators in design and testing (Lage, Borges, Canós & Vivacqua, 2011). It has also been noted that a balance must always be struck between virtual and real-world training (Taber, 2008). Furthermore, it may be possible to find opportunities for learning during events (Moynihan, 2009). All of the above mentioned issues are in need of further exploration.

When researchers set out to improve a system for emergency response, a model of the studied system segment may be used to uncover issues and needs, elicited through close collaboration with system users (e.g. first responders). There are numerous factors for quantitative analysis of ERS performance, for example detection time, preparation time, response travel time, travel distance, response time, incident duration and clearance time, human and property loss, environmental aspects and costs (Mendoça & Friedrich, 2004; Salaszyk & Lee, 2006). However, these measures do little to reveal system complexity and the impact of system interaction on outcomes (Dugdale, Darcy & Pavard, 2006). Instead, researchers have turned to qualitative analysis. Examples in the literature are observation analysis, social network analysis, interviews, task analysis, work domain analysis, cognitive work analysis, relation analysis, content analysis and artefact analysis (Uhr & Johansson, 2007; Norros & Salo, 2009; Abrahamsson, Hassel & Tehler, 2010; Borges, Engelbrecht & Vivacqua, 2011; Nemeth, Wears, Patel, Rosen & Cook, 2011; Stojmenovic, Dudek, Lindgaard, Noonan, Sen & Tsuji, 2011; Wickler, Hansberger, Potter & Tate, 2011). It has also been suggested that inspiration could be gathered from the field of risk and accident analysis. For example, FRAM (Hollnagel, 2004) enables researchers to reveal system coupling and emergent issues. Other methods from the risk analysis domain have also been mentioned, such as Reliability Analysis in the form of FMECA (Jackson, Faith & Willis, 2011). The implementation of system-oriented methods for modelling and evaluation is an area in need of further research.

In similarity to what has been found in the field of systems modelling and evaluation, current research on ERS design is profoundly user-centred. Moving away from technology-driven system development means to focus on system interaction and allowing for operator flexibility (Janssen, JinKyu, Bharosa & Cresswell, 2010). Applying a systems perspective on
design may also tackle the task-artefact cycle (Norros, Liinasuo & Hutton, 2011), by emphasizing the systemic effects of introducing new technology. Some researchers hold that emergency response systems should be designed to cover a broad range of incidents (Van de Walle & Turoff, 2008), in order to maximize the training potential of everyday activities and decrease the risk of surprises when large-scale incidents occur. In many respects, the same methods used in system modelling and evaluation can also be utilized to inform design processes. Additional methods mentioned in the literature are the Critical Decision Method, functional modelling (Norros, Colford, Hutton, Liinasuo, Grommes & Savioja, 2009), Core-Task Analysis, working with scenarios (Norros & Salo, 2009) and Cognitive Task Design (Hollnagel, 2005).
References


Quarantelli, E. (1995). Disasters are different, therefore planning for and managing them requires innovative as well as traditional behaviors (Preliminary paper no 221), University of Delaware, Disaster research centre.


