Department of Built Environment

Social contexts and narratives in knowledge management for situational awareness

Pekka Luokkala

Aalto University

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Social contexts and narratives in knowledge management for situational awareness

Pekka Luokkala

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Abstract

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Abstract

Crises require a quick and effective response performed by the response organization in order to minimize the negative consequences of the crisis, such as societal and economic costs and the number of deaths. The response actors and the response organization have to create and share situational information and to achieve situational awareness (SA). These goals are usually supported by information systems, such as common operational pictures (COP). However, the information systems also have problems which impede the user's achievement of SA: information overload and the complexity of the situational information. The problem of information overload refers to the challenges involved in perceiving the relevant situational information when a large amount of information are created and shared. The problem of the complexity of the situational information refers to the challenges involved in the comprehension of how the elements of situational information constitute an overall picture of the situation when put together. Reducing these problems would make the response more effective and reduce the negative effects of the crisis.

The main goal of this research is to reduce the problems of information overload and the complexity of the situational information in a crisis response. This research focuses on: 1) how SA is created both at the individual and organizational levels in the interactions that occur in a decentralized manner in several parts of the response organization and 2) how to reduce the problems of information overload and the complexity of the situational information. The analysis part of the research process includes data collection from four case studies and literature research. The design part includes developing a concept of a context-aware common operational picture (CACOP). The methods used in the development of the CACOP concept are conceptual and theoretical research and analogical reasoning in which human cognition is imitated. The demonstration of the conceptual solution is developed in a case study where the situational information relates to critical infrastructure failures.

The CACOP concept potentially reduces the above-mentioned problems. Based on the analysis of response organizations, SA is created in the form of a situational narrative in social contexts. In contrast to the many traditional COPs, the CACOP concept is developed on the basis of the analysis of the response organization from the perspective of knowledge management. CACOP identifies the context and supports the user in perceiving the elements of situational information relevant in that context and combining the elements of the situational information into the form of a situational narrative. Situational narratives support the CACOP user's comprehension of the overall picture of the situation.

Keywords crisis management, situational awareness, information overload, complexity of the situational information, social context, narrative

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Tiivistelmä

Kriisiorganisaatioiden on vastattava kriiseihin nopeasti ja tehokkaasti minimoidakseen kriisien negatiiviset seuraukset, kuten niiden yhteiskunnalliset ja taloudelliset kustannukset ja kuolemantapausten määrän. Vastatakseen kriiseihin tehokkaasti kriisiorganisaation täytyy luoda ja jakaa tilanneinformaatiota ja saavuttaa tilannetietoisuus. Näiden tavoitteiden saavuttamista tuetaan usein informaatiojärjestelmillä, joita ovat esimerkiksi tilannekuvajärjestelmät. Informaatiojärjestelmät voivat kuitenkin aiheuttaa myös onglemia jotka hidastavat tilannetietoisuuden saavuttamista. Tällaisia ongelmia ovat informaation ylikuorma ja kompleksisuus. Informaation ylikuorma viittaa tilanteeseen jossa luotujen ja jaettujen tilanneinformaation elementtien suuri määrä vaikeuttaa relevanttien elementtien havaitsemista. Tilanneinformaation kompleksisuus viittaa haasteisiin ymmärtää kuinka tilanneinformaation elementit liittyvät toisiinsa ja minkälaisen kokonaiskuvan ne muodostavat tilanteesta yhdessä. Näiden ongelmien vähentäminen tekisi kriisivasteesta tehokkaamman ja vähentäisin kriisien negatiivisia vaikutuksia.

Tämän tutkimuksen päätavoitteena on vähentää tilanneinformaation ylikuorman ja kompleksisuuden ongelmia kun tilannekuvajärjestelmää käytetään tilannetietoisuuden tukemiseen kriisivasteessa. Tämä tutkimus keskittyy 1) siihen kuinka tilannetietoisuutta luodaan vuorovaikutuksessa joka on hajautunut koko kriisiorganisaation laajuudelle ja 2) siihen kuinka voidaan vähentää informaation ylikuormaa ja kompleksisuutta. Tutkimuksen analyysiosa sisältää datan keräämisen neljässä tapaustutkimuksessa sekä kirjallisuustutkimusta. Suunnitteluosa sisältää kontekstitietoisen tilannekuvajärjestelmän (CACOP) konseptin kehittämisen. Suunnitteluosan menetelmänä on käsitteellinen ja teoreettinen tutkimus sekä analoginen päättely jossa imitoidaan ihmisen kognitiivisia toimintoja. Konseptia demonstroidaan tapaustutkimuksessa jossa tilanneinformaationa ovat häiriöt kriittisissä infrastruktuureissa.

CACOP-konseptin avulla on mahdollista vähentää informaation ylikuorman ja kompleksisuuden ongelmia. Kriisiorganisaation analyysissa havaittiin, että tilannetietoisuutta luodaan sosiaalisissa konteksteissa tilannenarratiivien muodossa. Toisin kuin useat perinteiset tilannekuvajärjestelmät, CACOP-konsepti on kehitetty tietojohtamisen näkökulmasta. CACOP-konsepti tunnistaa kontekstin, ja tukee käyttäjää havaitsemaan sellaisia tilanneinformaation elementtejä, jotka ovat relevantteja tunnistetussa kontekstissa, sekä yhdistämään näitä elementtejä tilannenarratiiviksi. Muodostetut tilannenarratiivit tukevat CACOP-konseptin käyttäjää tilanteen kokonaiskuvan ymmärtämisessä.

Avainsanat kriisinhallinta, tilannetietoisuus, informaation ylikuorma, informaation kompleksisuus, sosiaalinen konteksti, narratiivi

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Hannes Seppänen (DSc Tech.), Jaana Mäkelä (DSc Tech.), Jussi Nikander (DSc Tech.), Jari Korpi (DSc Tech.), and Zhe Zhang (MSc Tech.) have published joint journal articles with me. Pauli Alin (PhD) made valuable comments on the process of writing the third article. Jaana and Jari also traveled with me to Cartagena, Spain, and Columbus, Ohio. These trips were awesome, even though on our way to Columbus we forgot the conference posters at Chicago Airport.

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Espoo, 28 January 2017
Pekka Luokkala

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List of Abbreviations and Symbols

CACOP	Context-aware Common Operational Picture
CBAO	Command Body of the Area of Operation
CBSS	Command Body of Supporting Services
CCRRS	Command Center of Regional Rescue Services
COP	Common Operational Picture
GIS	Geographic Information System
GPS	Global Positioning System
iCM	interorganizational Crisis Manager
ICT	Information and communications technology
IFI	Infrastructure Failure Interdependency
INSPIRE	Infrastructure for Spatial Information in the European Community
IS	Information System
JMAC	Joint Mission Analysis Center
JOC	Joint Operations Center
KMS	Knowledge Management System
LOE	Limited Objective Experiment
MINUSTAH	UN Stabilization Mission in Haiti (Mission des Nations Unies pour la Stabilization en Haïti)
MISA-EM	Multinational Interagency Situational Awareness of the Extended Maritime Environment
MNE	Multinational Experiment
MOAC	Management of a Crisis Vocabulary
MOC	Maritime Operations Center

NATO ACT	North Atlantic Treaty Organization Allied Command Transformation
PIE	Precision Information Environment
SA	Situational awareness
SAGAT	Situation Awareness Global Assessment Technique
SAR	Search and rescue
SHIFT	Shared Information Framework and Technology
SII	Situational information interdependencies
SRSG	Special Representative of the Secretary-General
SSA	Shared situational awareness
UN	United Nations
USJFCOM	United States Joint Forces Command

List of Publications

This doctoral dissertation consists of a summary and of the following publications, which are referred to in the text by their numerals [1234]

1. Seppänen, Hannes; Mäkelä, Jaana; Luokkala, Pekka; Virrantaus, Kirsi. 2013. Developing shared situational awareness for emergency management. Elsevier. Safety Science, volume 55, pages 1-9. ISSN of journal: 0925-7535. DOI of article: 10.1016/j.ssci.2012.12.009.

2. Luokkala, Pekka; Virrantaus, Kirsi. 2014. Developing information systems to support situational awareness and interaction in time-pressuring crisis situations. Elsevier. Safety Science, volume 63, pages 191-203. ISSN of journal: 0925-7535. DOI of article: 10.1016/j.ssci.2013.11.014.

3. Luokkala, Pekka; Nikander, Jussi; Korpi, Jari; Virrantaus, Kirsi; Torkki, Paulus. 2016. Developing a concept of a context-aware common operational picture. Elsevier. Safety Science. ISSN of journal: 0925-7535. DOI of article: 10.1016/j.ssci.2016.11.005.

4. Seppänen, Hannes; Luokkala, Pekka; Zhang Zhe; Torkki, Paulus; Virrantaus, Kirsi. 2016. Critical infrastructure vulnerability – a method for identifying the infrastructure service failure interdependencies. International Journal of Critical Infrastructure Protection. ISSN of journal: 1874-5482.

Author's Contribution

Publication 1: Developing shared situational awareness for emergency management

The authors studied the creation of shared situational awareness in an SAR organization from three perspectives: information, communication, and trust. My perspective was communication. My contribution was equal to the contributions of Hannes Seppänen, who had the perspective of information, and Jaana Mäkelä, who had the perspective of trust. Kirsi Virrantaus made valuable comments during the writing process.

Publication 2: Developing information systems to support situational awareness and interaction in time-pressuring crisis situations

The authors define the common features of four case studies related to situational awareness and present a model of how situational awareness is created and shared in operations which have the corresponding features. I was the corresponding researcher and the corresponding author. Kirsi Virrantaus made valuable comments during the writing process.

Publication 3: Developing a concept of a context-aware common operational picture

The authors developed and presented the concept of a context-aware common operational picture which supports crisis response actors' need to perceive relevant situational information and to create and share situational narratives. I was the corresponding researcher and the corresponding author. Nikander, Korpi, Virrantaus, and Torkki made valuable comments during the writing process.

Publication 4: Critical infrastructure vulnerability – a method for identifying the infrastructure service failure interdependencies

The authors developed a method for identifying critical infrastructure failure interdependencies. I participated in conducting the study, and was responsible for conducting the study related to the ISFI matrix. I was responsible for writing the ISFI matrix method in the methods section, the ISFI matrix results in the results section, and contributing to the scientific discussion in the conclusion and discussion section. With Hannes Seppänen, I was responsible for writing the introduction, related research (excluding Sections 2.1 and 2.2), and materials and methods sections. Hannes Seppänen had the main responsibility for conducting the study and writing the article. Zhe Zhang contributed to the article by writing the theoretical review on expert knowledge collection (Section 2.1) and future research requirements in the conclusions and discussion. In addition, she reviewed and commented on the article. Paulus Torkki reviewed and commented on the article and acted as an advisor. Kirsi Virrantaus contributed at the beginning of the research by outlining the research idea. She reviewed and commented on the article and acted as the supervisor.

1. Introduction

1.1 Motivation and conceptual framework

Crises are characterized as low-probability/high-consequence events that threaten the most fundamental goals of an organization (Weick, 1988). Crises of this kind are, for example, man-made and natural disasters and they can cause serious societal and economic costs and even deaths (Baris, 2009). For example, in Haiti, the earthquake on 12 January 2010 caused over 100,000 deaths and the later cholera outbreak in October 2010 led to over 700,000 cholera cases and over 8,000 deaths (the estimates for the death toll vary, depending on the source). Another example of a crisis is the earthquake and tsunami in Japan on March 11, 2011, which resulted in more than 15,000 deaths and thousands of injured and missing people.

Crises require a quick and effective *response* performed by the *response organization* in order to minimize the negative consequences of the crisis (Römer et al., 2014).[3] The primary aims during the response are both rescue from immediate danger and stabilization of the condition of the victims. The tasks include, for example, relief, emergency shelter and settlement, emergency health, water, sanitation, and tracing and restoring family links (Wex et al., 2014). The response is defined as one of the phases in crisis management: the others include the mitigation phase (continuous steps taken to eliminate or reduce the risks of disasters), the preparedness phase (planning and training period before the disaster), the response phase (measures taken during and shortly after the disaster), and the recovery phase (the longer-term process of restoring the community to normal conditions) (Perry and Lindell, 2003; Wallace and Balogh, 1985; Wex et al., 2014).

A response organization is a temporary organization established to perform the response during the disaster. The response is usually described as measures taken by several organizations and teams with a decentralized and distributed manner of management, emphasizing flexibility and initiative in decision making and actions (Schraagen et al., 2010; Sorensen and Stanton, 2013; Wex et al., 2014). The response organization is established by several distinct organizations in cooperation, such as the organizations responsible for daily emergency situations, for example, the fire and rescue actors, medical actors, the police, and privately owned companies, non-governmental organizations, and other volunteers (Simpson et al., 2008).[3]

In order to respond effectively to crises, the *response actors* and the response organization have to create and share *situational information* and to create *situational awareness (SA)* effectively (Endsley, 2015).[1 2 3]

Situational information is dynamic, continually changing information that is mostly produced during a crisis. The situational information that is produced, such as that relating to incidents or resources, means the notifications that something is located or has happened in a specific location at a given time. Situational information can be, for example, incidents or warnings. Situational information has typically been visualized in relation to some static reference information (Dilo and Zlatanova, 2011; Seppänen, 2015).[1 3]

SA is the state of the knowledge about the situation. SA is created through a continuous and cyclic process called situation assessment or, simply, the SA process (Klein, 2009; Nofi, 2000; Smith and Hancock, 1995; Weick, 1988). Endsley (1988) defined SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". SA is divided into three separate levels: 1) perception, 2) comprehension, and 3) projection (Endsley, 1995a; 2000; Endsley et al., 2003). The first level in achieving SA has to do with perceiving the relevant elements of situational information. The second SA level involves comprehending what the perceived elements of situational information mean when taken together. Achieving the third SA level demands expertise. A person can only achieve the third level by comprehending the situation (level 2) and by understanding how the corresponding situations and the operations performed usually progress (Endsley et al., 2003).[1 2 3]

According to previous studies, the creation and sharing of situational information and the creation of SA are supported by *information systems* which enable the situational information to be produced, shared, and visually presented in such a way that all the situational information is available to all of the response actors in as real-time a manner as possible (Baber et al., 2013; Fanti and Beach, 2002; Goodchild et al., 2010; Laakso and Palomäki, 2013; Shelton, 2001; Steenbruggen et al., 2011; Vesterinen, 2008; Wolbers and Boersma, 2013). In the context of crisis management, IS is called by a variety of terms. In this dissertation, they are called *common operational pictures (COP)* (Vesterinen, 2008).[2 3]

The previous research on the issue of SA in crisis response has led to valuable results and the fast development of the COP systems, which enable the real-time creation and sharing of situational information during the crisis response. However, the COP systems designed from the perspective of IS also have problems which impede the user's achievement of SA. Two of these problems are focused on in this research; they are presented in Figure 1 and they are: 1) *information overload* and 2) *the complexity of the situational information* (Endsley et al., 2003).

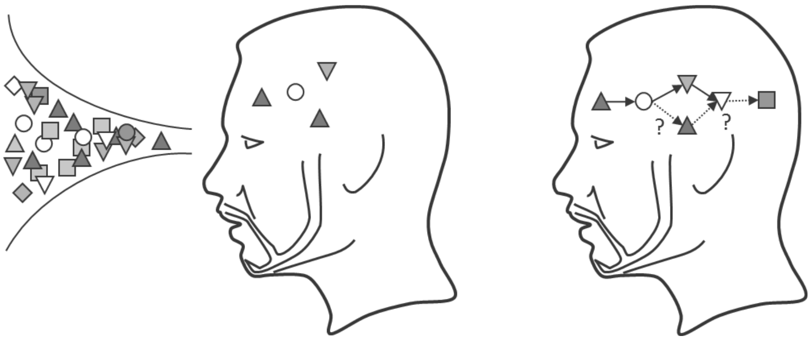

Figure 1. The problems of information overload (on the left-hand side, more situational information available than can be processed by the human "bandwidth") and the complexity of the situational information (on the right-hand side, challenges involved in the comprehension of how the elements of situational information are related to each other).

The problem of information overload refers to the challenges involved in perceiving the relevant situational information. This problem is significant in a crisis response, where a large number of the elements of situational information is created and shared. When all the actors in the crisis response organization and all the crowds/volunteers produce and share a large amount of situational information, the amount of irrelevant situational information increases from the viewpoint of an individual COP user (Alexander, 2014; Baber et al., 2013; Kamel Boulos et al., 2011; Korpi and Ahonen-Rainio, 2013; Endsley et al., 2003; Laakso and Palomäki, 2013; Liu, 2014; Netten and Someren, 2011; Schulz et al., 2012). The problem of information overload is associated with the achievement of the first SA level (Endsley et al., 2003).[3]

The problem of the complexity of the situational information refers to the challenges involved in the comprehension of how the elements of situational information are related to each other and how they constitute an overall picture of the situation when put together. The complexity of the situational information is caused by the large number of elements of situational information created and shared, the large number of potential interdependencies between these elements, and the unstructured nature of the situational information. The problem is significant in crisis response, where a large number of the elements of situational information is created and shared by several organizations which do not cooperate in daily operations. The elements of sector-specific situational information and the interdependencies such as causal relations between these elements are usually well known. However, there is usually a lack of comprehension of the cross-sector situational information interdependencies, the interdependencies between the elements of situational information created by several organizations, such as the cross-sector critical infrastructure failure interdependencies (Espada et al., 2015; Lewis, 2006). In addition, the cross-sector situational information interdependencies are challenging to identify and record because the knowledge of these interdependencies is often distributed among the experts' tacit knowledge in several organizations (Oliva et al., 2010).

The problem of the complexity of the situational information is associated with the achievement of the second and third SA levels (Endsley et al., 2003).

According to Turoff et al. (2004), Vescoukis et al. (2012), and Dorasamy et al. (2013), the perspective on the development of COPs needs to be shifted from IS to *knowledge management systems (KMS).* KMS refers to a class of information systems applied to managing organizational knowledge, instead of managing only the creation and sharing of information. KMS refers to an information system which supports the knowledge creation, storage, and reuse processes, providing a shared knowledge space with the use of a consistent and well-defined vocabulary, modeling and explicitly representing knowledge, permitting collaborative efforts between users, and allowing reusable knowledge (Alavi and Leidner, 2007; Dorasamy et al., 2013). KMS refers to an effective tool to enable the knowledge management processes. In this context, a KMS is the key enabler of knowledge management (Dorasamy et al., 2013).[3]

The development of COPs from the perspective of KMS is still in its infancy. Even though there is a demand for COP systems designed from the perspective of KMS, there is a lack of understanding of the response organization from the perspective of knowledge management, which would give the requirements for the design of COPs from the perspective of KMS.[3]

Knowledge management refers to the activity of helping an organization to create, capture, codify, store, share, and apply knowledge effectively (Dorasamy et al., 2013) and identifying and leveraging the collective knowledge in an organization to help the organization to compete (Alavi and Leidner, 2007), and the strategic activity of dynamic knowledge creation (Nonaka et al., 2000; Torell, 2005). Managing both tacit and explicit knowledge is the challenge of knowledge management (Alavi and Leidner, 2007; Nonaka and von Krogh, 2009; Dorasamy et al., 2013).

In knowledge management, the term *knowledge* refers to subjective and context-specific human knowing (Nonaka, 1994; Nonaka et al., 2000; Nonaka and von Krogh, 2009; Tsoukas, 1996). In contrast to knowledge, *information* is external messages that are perceived and interpreted against knowledge (Nonaka, 1994). However, the interactive model (data & knowledge->information) specifies that information cannot be entirely separated from the human agent as an information processor. Instead, *data* appear as information when a human agent is interpreting them against his/her knowledge (Boisot and Canals, 2004; Kettinger and Li, 2010).[2]

In knowledge management, knowledge is usually divided into two types: *explicit* and *tacit knowledge* (Dyer and Nobeoka, 2000; Evans, 2008; Grant, 1996; Klein, 2009; Nonaka et al., 2000; Nonaka and von Krogh, 2009; Tsoukas, 1996; Weick and Roberts, 1993). Explicit knowledge has a universal and context-free character. It is accessible through consciousness (Evans, 2008; Nonaka and von Krogh, 2009) and it is easy to express in formal language (Evans, 2008; Grant, 1996; Nonaka et al., 2000; Nonaka and von Krogh, 2009). Some authors also equate explicit knowledge with information and use the terms interchangeably (Dyer and Nobeoka, 2000; Grant, 1996). In contrast to explicit knowledge, tacit knowledge, for example intuitions and practical know-how, is nonverbal and difficult to formalize. It is revealed through its application in a particular context (Dyer and Nobeoka, 2000; Evans, 2008; Grant, 1996; Nonaka et al., 2000; Nonaka and von Krogh, 2009). Tacit knowledge is more difficult to access through conscious choices (Evans, 2008; Nonaka and von Krogh, 2009). Tacit and explicit knowledge are not separate but mutually complementary (Evans, 2008; Nonaka and von Krogh, 2009; Tsoukas, 1996). Tacit knowledge is a necessary component of all knowledge and explicit knowledge is always grounded in a tacit component (Evans, 2008; Klein, 2009; Tsoukas, 1996).[23]

1.2 Author's background and research environment

The backgrounds which led the author to become involved in this research are his previous involvement in the project of developing a COP system called interorganizational Crisis Manager (iCM) and a Master's thesis (Luokkala, 2009) in which he considered the cooperation between Finnish marine operators (the Navy, the Border Guard, and the Maritime Administration). These backgrounds also potentially affect the performance of this research.

The author was employed in Insta DefSec in a project where the iCM system was developed. The iCM system was applied as a software platform in Multinational Experiment 5 (MNE 5), in which the Shared Information Framework and Technology (SHIFT) concept was developed (Vesterinen, 2008; Virrantaus et al., 2009). A view of the user interface of the SHIFT concept is presented in Figure 2. MNE 5 was a part of the MNE series organized by the United States Joint Forces Command (USJFCOM). The MNE series is the USJFCOM's multinational concept development and experimentation element (USJFCOM, 2011). MNE 5 was a multi-agency crisis management experiment that took place during the years 2006-2008. In addition to MNE 5, SHIFT was used in four Finnish search and rescue (SAR) and military exercises, and it was also tested in the international Barents Rescue exercise in 2007. The author was not involved in MNE 5 or other exercises where SHIFT was used, but the other researchers (Korpi and Ahonen-Rainio, 2010; Virrantaus et al., 2009) in the Geoinformatics research group (in which this research and this doctoral dissertation were undertaken) were involved in those exercises.

The author joined the Geoinformatics research group in order to implement his Master's thesis in the year 2009 after his employment in Insta DefSec. In his Master's thesis, the author studied the cooperation between Finnish marine operators from the perspective of knowledge management and especially utilizing the method of identifying social contexts. In that Master's thesis, social contexts are the different types of interactions which occurred between the marine operators in order to create SA.

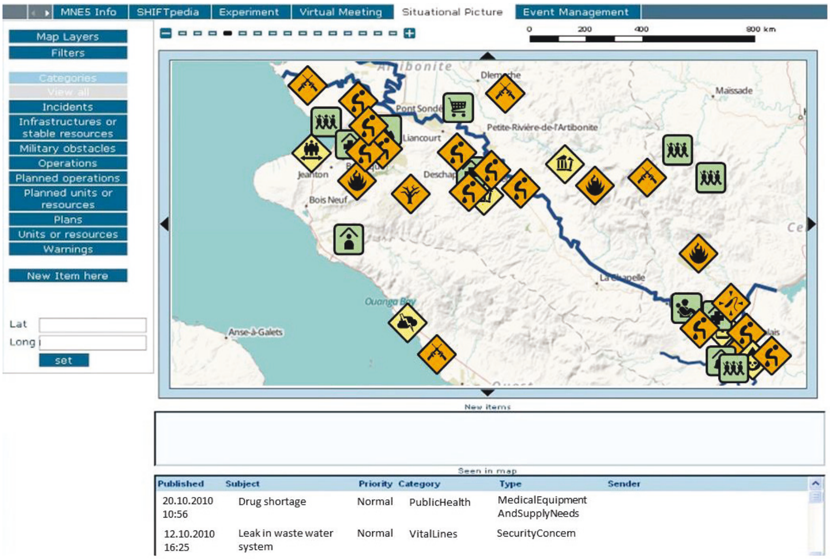

Figure 2. A view of the user interface of the SHIFT concept. The map (OpenStreetMap Humanitarian map layer) and the situational information have been added to a screenshot image taken from the SHIFT concept. Overlapping instances indicate the problem of information overload.

Other researchers in the Geoinformatics research group have studied widely different themes in crisis and disaster management, including, for example, the graphic design of situational information (Korpi, 2015; Korpi and Ahonen-Rainio, 2010; 2013; 2015; Korpi et al., 2014), situational information requirements and quality (Seppänen, 2015; Seppänen and Virrantaus, 2015; Seppänen et al., 2013), maturity models for the evaluation of the development of shared situational awareness (Mäkelä, 2013; Mäkelä and Virrantaus, 2013), COP user profiling (Multimäki et al., 2010) and the usability of COP methods, and GIS-based methods in crisis management (Seppänen and Virrantaus, 2010; Špatenková, 2009; Virrantaus et al., 2009, Zhang et al., 2014).

1.3 Previous research relating to the topic

The previous research relating to the research topic is divided into the themes of response organizations, the recent developments of COPs, including the methods which aim to reduce the problems of information overload and the complexity of the situational information, and the defined requirements for the design of COPs.

1.3.1 Response organization

According to the previous studies, a crisis response organization is often a combination of integrated hierarchies and dynamic networks of teams. The integrated hierarchies consist of the organizations responsible for daily emergency situations, for example the fire and rescue actors, medical actors, and police. In smaller emergency situations, these organizations are hierarchical by nature and the communication processes are mostly vertical. In larger crises such as natural disasters, these hierarchies are often integrated through temporary management teams at several levels of the organizational hierarchy. The temporary management teams ease the horizontal and inter-organizational communication processes. Several teams which offer supporting services also join the response organization temporarily, which gives the response organization the character of a dynamic network. The supporting teams do not necessarily participate in the actual operations, but they offer information and services needed during the response. The actors of this kind include, for example, airline companies, airport companies, voluntary rescue services and other voluntary groups, religious organizations, financial institutions, the media, military organizations, and travel companies. Some supporting teams join the response organization only during the period when a particular supporting service is needed (Baris, 2009; Dorn, 2009; Klein, 2009; Rimstad et al., 2014; Römer et al., 2014; Schraagen et al., 2010; Simpson et al., 2009; Uhr et al., 2008; Valtonen, 2010; Wex et al., 2014; Wolbers and Boersma, 2013).[23]

One example of a response organization is the organization running the United Nations (UN) Stabilization Mission in Haiti (in French, Mission des Nations Unies pour la Stabilization en Haïti or MINUSTAH). MINUSTAH is one of the pioneers of intelligence-led UN operations which combine several military, police, and civilian organizations during the operations through the management teams of the Joint Mission Analysis Center (JMAC) and the Joint Operations Center (JOC). The JMAC and JOC are managed by a Special Representative of the Secretary-General (SRSG). In MINUSTAH, the JOC is responsible for information on current operations and day-to-day situation reporting, whereas the JMAC is responsible for medium- and long-term analysis. In practice, the JMAC has performed much deeper analysis. For example, weather and current military information came primarily from JOCs, while the implications of that information might be analyzed by the JMAC (Dorn, 2009).

1.3.2 Recent developments of COPs

In scientific literature, several terms are used for the COP concept. A COP is called, for example, a situational picture (Multimäki et al., 2010; Vesterinen, 2008), situation awareness system (Laakso and Palomäki, 2013), and emergency management information systems (Dorasamy et al., 2013). These terms refer to the information systems or knowledge management systems which are developed in order to support SA and decision making during a crisis response. They enable the situational information to be produced, shared, and visually presented in such a way that all the situational information is available to all of the actors involved in the crisis response in as real-time a manner as possible and support communication during the crisis response (Baber et al., 2013; Laakso and Palomäki, 2013; Shelton, 2001; Steenbruggen et al., 2011; Vesterinen, 2008; Wolbers and Boersma, 2013).[23]

Geographic information plays a big role in crisis management and in COPs, because most of the information has a geospatial location. A simple map of the environment is essential information for the rescue personnel and mashup technology has enabled event information to be plotted on top of a background map (Field, 2008; Kamel Boulos et al., 2011). In addition to offering a geospatial context for the event information, geographic information can be used in analyzing the operational environment. Analyses of such features as terrain accessibility (Blanford et al., 2012), chemical dispersion (Malizia et al. 2012), and the vulnerability of urban areas (Zhang et al., 2014) are useful tools in crisis preparedness and response. The amount and the availability of geospatial information have increased enormously during the last decade (Vescoukis et al., 2012; Alamdar et al., 2016). Technological advances such as the emergence of social media and the affordability of GPS devices have made citizens into sensors who produce the geospatial "background" information on collaborative platforms such as OpenStreetMap (Leventhal, 2012), as well as situational information by using tweets and text messages (Corbane et al., 2012). Sensor networks (Kamel Boulos et al., 2011) and UAVs (Römer et al., 2014) are also able to produce geospatial information. At the political level, directives such as Infrastructure for Spatial Information in the European Community (INSPIRE) make geospatial data more available for those who need them. Alamdar et al. (2016) underline the point that the fast development of the sensors and the increased availability of geospatial information have created a need for a method for integrating information gained from several sources. They present a GIS-based software tool that enables the integration of sensor information in order to produce situational information for the support of SA in crisis response.[3]

In recent years, the production of situational information has been supported through crowdsourcing, which means that the task of producing situational information is outsourced to crowds. For example, the citizens living in the crisis area can be requested to become involved in crowdsourcing and provided with the tools they should use in the information collection and processing. In crowdsourcing, the information they process in order to produce situational information can be collected, for example, from social media, such as tweets produced by Twitter users (Goodchild et al., 2010; Corbane et al., 2012; Alexander, 2014; Camponovo and Freundschuh, 2014; Liu, 2014). One of the most commonly used systems for the processing of the situational information produced through crowdsourcing is the Ushahidi platform. The Ushahidi platform has been used in several crises. For example, in the Haiti earthquake the Ushahidi platform was used in mapping more than 3500 reports sent by the crowd in the disaster zone to the free number via text messages (Corbane et al., 2012; Camponovo and Freundschuh, 2014).

When data are processed through COP systems, they become situational information, which means instances which are linked to predefined classes. Classes are general models of similar instances. Classes define which attribute information can be added to an instance and how the instance is visualized in a COP. Attributes typically include the location and the time of the instance, as well as qualitative or thematic information on the instance. For example, if the instance is an incident, the qualitative or thematic information can be the size of the incident or the area affected by the incident. In COPs, classes can be utilized in the methods which reduce information overload, such as visualization methods, filters, and methods for merging and clustering duplicate instances (Ortmann et al., 2011; Vesterinen, 2008). One example of the classification of instances is the Management of a Crisis (MOAC) vocabulary. MOAC is a lightweight vocabulary that aims to provide terms to enable practitioners to relate different "things" in crisis management activities to one another (Ortmann et al., 2011).[3]

The problem of information overload is a common challenge in visualization disciplines such as cartography (Regnault and McMaster, 2007) and information visualization (Ellis and Dix, 2007). In cartography, the amount of content and symbolization is adapted to the scale by using automated generalization operators (Regnault and McMaster, 2007), and in information visualization the user is provided with clutter reduction tools that assist him in the visual analysis of large datasets (Ellis and Dix, 2007). From the point of view of visualization, COPs are often examples of map mashups, where the situational information (e.g., events) is overlaid on top of a background map (e.g., Sahana, 2016; Crowdmap, 2016; GeoChat, 2016). The management of visual overload can be performed with the tools provided in the user interface of a map mashup. In addition to filtering/selection, methods are also available for the clustering/aggregation, refinement, displacement, typification, symbolization, spatial distortion, and animation of event information (Korpi and Ahonen-Rainio, 2013). The map can be linked to other views of the information (Mazumdar et al., 2014).[3]

A typical way to reduce the information overload in a crisis response is through filtering methods (Kamel Boulos et al., 2011; Imran et al., 2015; Netten and Someren, 2011; Nishida et al., 2003; Vescoukis et al, 2012). Nishida et al. (2003) classified the filtering methods into three categories; cognitive filtering, social filtering, and economic filtering. In cognitive filtering, the interests of the users are the basis for information selection. The prediction of the user's interest becomes a key part of the technology for the full and proper operation of this function. Social filtering is conducted on the basis of the mutual relationship between the users of the function and senders of messages in the user's organization. Therefore it is essential to know the relationships among all the parties that are using the system. In economic filtering, information is selected on the basis of the ratio between the profit gained from the information and the cost of obtaining it. Vescoukis et al. (2012) also classified the filtering methods into three categories; time filtering, space filtering, and quality filtering. Time filtering removes the temporal data redundancy, while space filtering aims at reducing the spatial redundancy. Quality filtering re-quantizes the geospatial content to reduce the amount of information transmitted. One example of cognitive filtering (which is the branch of the scientific literature to which this research contributes) is the manual filtering method in the SHIFT concept. In SHIFT, the user can manually select the classes from which he wants instances to be visualized on the map layer (Vesterinen, 2008). Another, more sophisticated example of cognitive filtering methods is the service called the Precision Information Environment (PIE), presented by Kamel Boulos et al. (2011). In order to reduce information overload, PIE offers each user a profile which is based on the role of that user in a crisis response organization. The profile helps the user to get the right information at the right time and to avoid information overload by filtering information in such a way that only what is relevant is given to all the users. In this way, the user can stay focused on the tasks and activities that matter. The roles and the relevance of the situational information for the roles are defined in advance, but the relevance of the situational information is tunable by the user. The user can manually adjust the relevance score for each element of the situational information. This allows the user to focus on content that is personally of interest to him according to his current activity (Kamel Boulos et al., 2011).[3]

One of the reasons behind the problem of information overload is duplication. If situational information is collected from a variety of sources, such as when crowdsourcing is utilized, several instances reported to the information system may be reports from one and the same incident. The problem of duplicates can be reduced through merging the duplicates into one instance or creating clusters of duplicates (Schultz et al., 2012). Both methods require the adequate matching of the instances on the basis of their time, location, and the type of the reported instance (class). The classification of situational information and a semantic database of instance classes are required in order to find the matches of duplicate instances (Imran et al., 2015; Schultz et al., 2012).[3]

The availability of scientific publications related to the complexity of the situational information and the situational information interdependencies appears to be somewhat limited, except for the field of critical infrastructure protection, where the theme is widely discussed using the terms infrastructure failure interdependencies (IFI) or interdependency failures (Chang et al., 2007; Hasan and Foliente, 2015; Lewis, 2006; Little, 2002; McDaniels et al., 2007; McDaniels et al., 2015). Critical infrastructure, also called vital infrastructure or the lifeline system, is a network of independent, mostly privately owned systems that function collaboratively to produce and distribute a continuous flow of products and services so vital that its incapacity or destruction would have a weakening impact on societal functions and national security (Marsh, 1997; Lewis, 2006). Critical infrastructure includes several sectors, such as telecommunications, energy, transportation, and water (Chang et al., 2007; Espada et al., 2015; Galbusera et al., 2015; Hernandez-Fajardo and Dueñas-Osorio, 2013; Lewis, 2006; Utne et al., 2011).[4]

As critical infrastructures are interconnected on several levels, a failure in one system can cause failures in other systems. These causal links are called IFIs (Chang et al., 2007; Hasan and Foliente, 2015; Lewis, 2006; Little, 2002; McDaniels et al., 2007; McDaniels et al., 2015). The extreme situation that can potentially develop through infrastructure failure interdependencies is a so-called cascading failure (also called a cascade failure). Cascading failures are large-scale failures that begin with a relatively insignificant failure which propagates throughout a major portion of the infrastructure and potentially spreads to the other systems as well (Benjamin et al., 2015; Espada et al., 2015; Eusgeld et al., 2011; Hasan and Foliente, 2015; Hernandez-Fajardo and Dueñas-Osorio, 2013; Lewis, 2006; Little, 2002; Ouyang and Wang, 2015; Panteli and Mancarella, 2015). The risk of a cascading failure is particularly significant when a failure occurs in systems in the energy sector, such as a failure in a power line, which can escalate to a bigger failure through infrastructure failure interdependencies and also cause failures in other systems, such as in the water and transportation systems, which in turn can cause further societal impacts (Bo et al., 2015; Hasan and Foliente, 2015; Lewis, 2006; Panteli and Mancarella, 2015; Ren and Watts; 2015).[4]

The comprehension of infrastructure failure interdependencies is important in the protection of critical infrastructure, especially from the viewpoints of mitigation, preparedness, and the response (Chang et al., 2007; Espada et al., 2015; Hasan and Foliente, 2015; Lewis, 2006). In preparedness, the infrastructure failure interdependencies should be well known in order to develop the systems' resilience against the causes of failures in order to reduce the vulnerabilities in the critical infrastructures and to prevent cascading failures from taking place (Chang et al., 2007; Hasan and Foliente, 2015). In the response, the comprehension of the potential infrastructure failure interdependencies enables the development of SA and information sharing between the various systems (Panteli and Mancarella, 2015). The sector-specific infrastructure failure interdependencies are usually well known. However, because the critical infrastructures are independent and mostly privately owned systems, there is usually a lack of comprehension of cross-sector infrastructure failure interdependencies, which are infrastructure failure interdependencies between several systems (Espada et al., 2015; Lewis, 2006). According to Espada et al. (2015), "Assessment and mitigation of cascading failures across infrastructures are the most challenging problems in critical infrastructure protection."[4]

Despite the fact that the identification of the infrastructure failure interdependencies is vital to the protection of the critical infrastructure, the availability of related scientific publications appears to be somewhat limited. The lack of discussion of qualitative methods for identifying IFIs may be related to the fact that the detailed information about IFIs is highly sensitive (Laugé et al, 2015) and in most cases the private critical infrastructure operators are reluctant to share information about IFIs and failures with the research community (Rahman et al., 2006). In addition, some of the methods are relatively difficult and expensive to organize, such as the interviewing methods (Chang et al., 2007). In addition, in the scientific publications that focus on identifying infrastructure failure interdependencies, the more detailed focus is still on the methods for classifying the critical infrastructures and the IFIs, while the methods for collecting data are often ignored or explained quite briefly (Chang et al., 2007; Rinaldi et al., 2001).[4]

Three publications, Chang et al. (2007) and McDaniels et al. (2007; 2015), identify IFIs primarily from public news stories. In addition, they present a framework and a database for the identification of IFIs. IFIs were identified from the public news stories which describe the crises of the 1998 Ice Storm in Canada (Chang et al., 2007; McDaniels et al., 2007), the 2003 blackout in North America (McDaniels et al., 2007), and the 2004 series of hurricanes (Charley, Frances, Jeanne) in Florida (McDaniels et al., 2007).[4]

Laugé et al. (2015) identified IFIs using an online questionnaire. Experts associated with critical infrastructure organizations located in countries in Europe, North America, and Asia were contacted by email and requested to participate in the survey. The experts were asked to evaluate the magnitude (scale from: 0 = no effect, to: 5 = very high effect) of a failure which would occur in their own critical infrastructure if a failure occurred in another critical infrastructure on such a level that it was unable to deliver products and services for the expert's own critical infrastructure during a certain period of time (six different time periods). As a result, tables were created which show the magnitudes of the infrastructure failure interdependencies between 11 critical infrastructures: energy, ICT, water, food, health, financial, public and legal order and safety, civil administration, transport, the chemical and nuclear industry, and space and research. The research considers the critical infrastructures as monolithic entities and the results offer general-level information about the infrastructure failure interdependencies, but not detailed information, such as which parts of the critical infrastructure would fail because of failures in some parts of another critical infrastructure.[4]

Instead of the identification of the IFIs, the scientific publications focus more on the reasons for and the effects of the threats and interdependencies of critical infrastructures, such as storms and the economic costs caused by these (Bo et al., 2015; Greenberg et al., 2007; Hines et al., 2009; Panteli and Mancarella, 2015; Tomaszewski and Bartodziej, 2011), and the simulation and other methods which make it possible to analyze the cascade failures of specific scenarios after the IFIs have been identified (Beccuti et al., 2012; Benjamin et al., 2015; Espada et al., 2015; Galbusera et al., 2015; Little, 2002; Marrone et al., 2013; Oliva et al., 2010; Ouyang and Wang, 2015; Ren and Watts, 2015; Utne et al., 2011).[4]

1.3.3 Defined requirements for the design of COPs

Turoff et al. (2004), Vescoukis et al. (2012), and Dorasamy et al. (2013) defined the requirements for the design of COPs. The connecting feature of the requirements they defined is that the perspective on the development of COPs needs to be shifted from information systems to the KMS which support the knowledge management processes in a more comprehensive way. A knowledge management system refers to a system which supports knowledge creation, storage, and reuse processes, provides a shared knowledge space with the use of a consistent and well-defined vocabulary, models and explicitly represents knowledge, permits collaborative efforts between users, and allows reusable knowledge. The perspective of knowledge management would offer a better starting point for reducing the problems of information overload and the complexity of the situation.[3]

Turoff et al. (2004) developed design principles for a Dynamic Emergency Response Management Information System (DERMIS) based on the design premises identified through studying the use of the Emergency Management Information System and Reference Index (EMISARI) and design concepts resulting from a literature review. According to their design premises, the system should offer its users efficient filters which attempt to prevent information overload; the system needs to be designed in such a way that it can be evolved and improved from its prior usage, and the system needs to support the formation and functioning of temporary teams of appropriate experts from several backgrounds which aim to solve specific problems. The design concepts they defined are metaphors, roles, notifications, context visibility, and hypertext. Metaphors are mental models that make it easier to understand the complex systems of crisis situations. In a crisis response, the metaphor can be the event log. Human roles are specific privileges and tools of the user of the information or communication systems for carrying out the actions addressed to the roles. Notifications are relevant alerts to a user of changes in status, data, and/or information of concern for the given user, brought about by events and/or the actions of other users. Context visibility is the idea that the elements of the situational information are presented in a context that relates to the understandings of the user. Hypertext means the semantic relations between the elements of situational information. The following design principles have been formed. The system should provide a hierarchical structure for all the data and information currently in the system. The system must be viewed as an open communication process among all those involved in the response organization. The system needs to include semantic memory which provides rules about events and their interactions and interdependencies. The system needs to offer the tools for the formation and functioning of temporary online teams of appropriate experts from several backgrounds.[3]

Vescoukis et al. (2012) proposed the design requirements for the architecture of decision support systems in environmental crisis management. They underline the point that the rapid development of sensors which produce situational information will exacerbate the problem of information overload, and therefore, there will be a need for more effective, context-aware methods for the filtering and visualization of situational information. They propose that context-aware filtering and visualization methods can be developed through combining the time, space, and quality filtering methods.[3]

Dorasamy et al. (2013) performed a comprehensive review of previous work related to information systems and knowledge management systems in a crisis response. They identified the fact that a number of researchers do not necessarily mention the terms knowledge management or knowledge management systems in the context of crisis management. In this regard, a need exists to differentiate clearly between an information system and a knowledge management system in crisis management. They propose that researchers working on knowledge management system design in the context of crisis management should take the following issues into consideration. The knowledge management system design should enable the creation of an evolving knowledge structure. Well-designed knowledge management systems enable individuals and teams to continuously and seamlessly make changes to the disaster knowledge base. They should also support both the informational and the knowledge requirements of different roles played by response actors and coordination efforts through feedback during the different phases of a crisis situation, and support interactions and conversations between the people involved in disaster management.[3]

More research is needed in order to understand the response organization and the SA creation processes from the perspective of knowledge management. Developing the understanding of the response organization would give the requirements for the design of COP systems from the perspective of KMS. In addition, there is a need to research and develop the tools and methods for COPs. Through the development of COP tools which would reduce the problems of information overload and the complexity of the situational information, the response would become more effective and the societal and economic costs and the number of deaths of the crises could be reduced.

This research focuses on studying the nature of response organizations from the perspective of knowledge management and designing COP systems from the perspective of KMS.

1.4 Objectives and scope

The main goal of this research is to reduce the problems of information overload and the complexity of the situational information when using a COP in a crisis response. Reducing these problems would support COP users in achieving the first and second SA levels. This would make the response more effective and reduce the negative effects of the crisis, such as societal and economic costs and the number of deaths.

This research endeavors to answer two research questions derived from the two research problems. The existence of the first research problem contributed to the existence of the second research problem. The research problems are:

Research problem 1: There is a lack of knowledge of how SA is created both at the individual and organizational levels in the interactions that occur in a decentralized manner in several parts of the response organization. In other words, there is a lack of understanding of the response organization from the perspective of knowledge management.

Research problem 2: The existing COPs do not support the processes of SA creation in the response organization efficiently enough. This is due to the fact that COPs are designed from the perspective of IS instead of KMS. The problems related to the ability of the existing COPs to support SA creation are information overload and the complexity of the situational information.

This research includes two research questions which have been derived from the research problems. The research questions are:

Research question 1: How is SA created both at the individual and organizational levels in the interactions that occur in a decentralized manner in several parts of the response organization? The goal is to analyze and describe the response organization from the perspective of knowledge management.

Research question 2: How can the problems of information overload and the complexity of the situational information be reduced? The goal is to develop new conceptual solutions for the design of a COP from the perspective of KMS supporting the processes of SA and SSA creation in the response organization.

This research is a part of the wider scope of the research themes in crisis and disaster management investigated in the Geoinformatics research group. The themes of the other researchers described in Chapter 1.2 are not within the scope of this research. The focus of this research is on developing methods for the response phase in crisis management as defined by Wex (2014). As one of the tasks in the mitigation phase is to develop the ability to respond, this research includes the mitigation phase. The recovery phase is not within the scope of this research. In the context of the response phase, the focus of this research is on the conceptual development of the solutions which support SA in the response phase. The implementation of the conceptual solutions as prototypes and the validating user tests are not within the scope of this research. In addition, the processes that form the unstructured data of situational information, possibly collected through crowdsourcing, into the form of the elements of situational information are not within the scope of this research.

The logic of how the articles and the research questions of this compilation dissertation are interconnected is presented in Figure 3. Articles and research questions can be connected in two ways. Some of the articles (my contribution in the articles) define the research questions of this dissertation explicitly so that the results of these articles answer the research questions of this dissertation. Another way they can be interconnected is that the articles offer supplementary material for the definition of the research questions, not in the results, but in other parts of the articles, such as the introduction or theoretical framework.

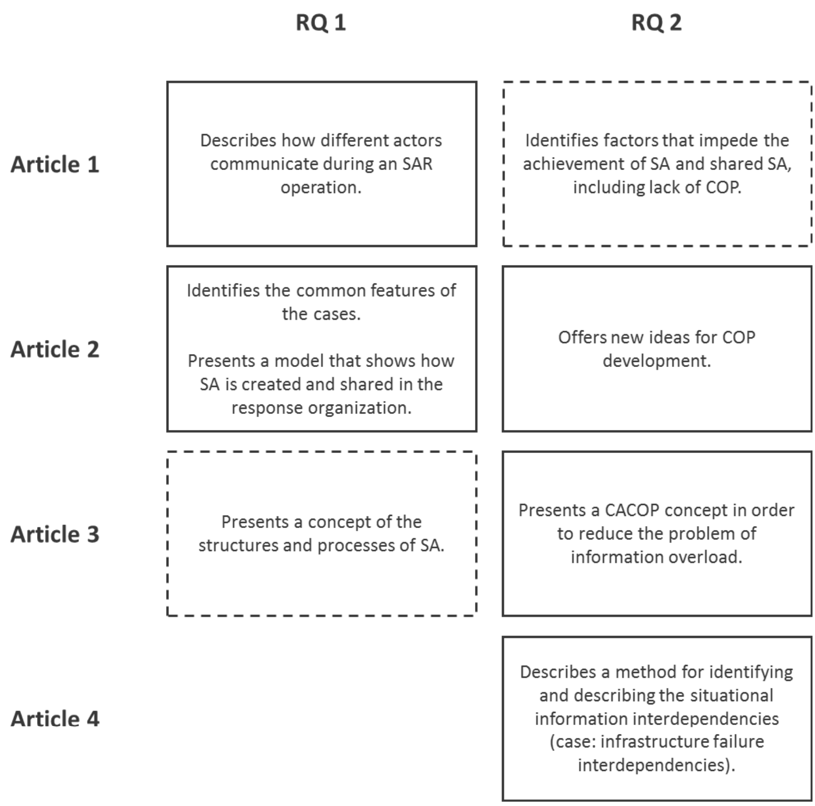

Figure 3. The logic of how the articles and research questions are interconnected. The type of "the article defines the research questions explicitly" is visualized through a solid line and the type of "the articles supplement the definition of the research questions" is visualized through a dashed line.

1.5 Research process and structure of the dissertation

The research process is divided into two parts: 1) the analysis and descriptive part and 2) the conceptual design part. This structure comes from the two research problems defined in Chapter 1.4. The analysis and descriptive part answers the first research question and the design part answers the second research question.

1.5.1 Analysis and descriptive part

The goal of the analysis and descriptive part is to analyze and describe the response organization from the perspective of knowledge management; how SA is created both at the individual and organizational levels in the interactions that occur in a decentralized manner in several parts of the response organization. The descriptive part includes the case studies and the development of the general model of the response organization based on data collected from the case studies and the literature research.

Data were collected from four case studies using the interviewing method and the observing method. The cases were: the SAR 2009 exercise, SAR 2010 exercise, MNE 6 LOE 2, and TIETO 2011 exercise. The cases are presented in a more detailed way below, and after that follows a more detailed description of the data collection methods used in the case studies.

The result of the analysis and descriptive part is the description of the response organization from the perspective of knowledge management. The material used in this description is the data collected from the cases and the theories of SA and SSA, which will be described in Chapter 2.1, and the knowledge management approaches of social contexts and narratives, which will be described in Chapter 2.2.

SAR 2009 and SAR 2010 exercises

The SAR 2009 and the SAR 2010 exercises were two of the annual Finnish SAR (search and rescue) exercises organized to maintain and improve preparedness for SAR operations related to possible plane accidents near Helsinki Airport. The response organization in the SAR exercises consists of four management teams. At first, the Emergency Response Center is responsible for the initial assessment of the situation and for alerting actors according to the assessment. After that, several public organizations form temporary management teams called the Command Center of Regional Rescue Services (CCRRS), the Command Body of the Area of Operation (CBAO), and the Command Body of Supporting Services (CBSS). The CCRRS manages the CBAO and the CBSS and informs the media about the progress of the situation. The CBAO manages the SAR operations in the field, and it is formed close to the accident. It typically consists of police, medical, and rescue services. The CBSS provides the supporting activities, such as psychological services, for the patients and the victims' families.[2]

In the scenario for the SAR 2009 exercise, a plane crash-landed in the sea close to the southern Finnish shoreline of the Baltic Sea, the Gulf of Finland. The exercise concentrated on the management entities, but there were also real actors searching for and rescuing those acting as the victims. The exercise lasted for one day. The situation in the SAR 2009 exercise was relatively well ordered because the exercises are held annually. However, the maritime scenario was exceptional and it changed the compositions of the teams and the procedures for the operating system. The events and actions during the exercise progressed in the usual way and the situation was relatively predictable. Additionally, the procedures of the CBAO were more developed and established than the CBSS's procedures.[2]

In the scenario for the SAR 2010 exercise, the plane landed on a runway without any landing gear. The exercise concentrated only on the management teams. There were no real actors searching for and rescuing those acting as the victims in the exercise. Instead, the progression of the situation was handled by the management teams providing them with scripted situational information. The exercise lasted for one day. The situation in the SAR 2010 exercise was relatively well ordered. Because the exercises are held annually, the structure and the procedures of the operating system are well established. The events and actions during the exercise progressed in the usual way, and the situation was relatively predictable. However, the procedures of the CBAO were still more developed and established than the CBSS's procedures.[2]

MNE 6 LOE 2

The Multinational Experiment 6 (MNE 6) exercise was a part of the MNE series organized by the USJFCOM. The MNE series is the USJFCOM's multinational concept development and experimentation element (USJFCOM, 2011; Vuorisalo, 2012). During the MNE 6 campaign, a series of workshops and two Limited Objective Experiments (LOE) were organized (Koskinen-Kannisto, 2013; USJFCOM, 2011).[2]

The scenario-based LOE 2 was organized in Cartagena, Spain, between April 26th and April 30th, 2010. The participant partners were Finland, France, Germany, the NATO ACT, Poland, Singapore, Spain, Sweden, the Combined Joint Operations from the Sea Center of Excellence, and the United States (Vuorisalo, 2012). The scenario included threats and events harmful for maritime transportation in the Gulf of Aden and along the eastern coast of Africa, where data gathering is supposed to be difficult. The situation was designed to be realistic and included the relevant stakeholders, namely Interpol and the UN. The activities of the stakeholders were handled by role players and there were no activities in the field (Koskinen-Kannisto, 2013).[2]

In LOE 2, the MNE 6 campaign tested the concept of Multinational Interagency Situational Awareness of the Extended Maritime Environment (MISA-EM) (Koskinen-Kannisto, 2013; USJFCOM, 2011; Vuorisalo, 2012). The MISA-EM included procedures and information sets that would supposedly enable Maritime Operations Centers (MOC) to achieve a better SA. The concept of MISA-EM was tested by comparing the SA of two MOCs while they were reacting to scenario injects. The MOCs consisted of the MISA-EM MOC, which had been equipped with MISA-EM procedures and information sets, and the Non-MISA-EM MOC, which, in turn, operated without MISA-EM procedures and information sets. The SA of the MOCs was surveyed using the Situation Awareness Global Assessment Technique (SAGAT) (Endsley, 1995b) and by making observations (Koskinen-Kannisto, 2013).[2]

The author participated in the MNE 6 LOE 2 campaign as an analyst. In addition to the goal of surveying and comparing the SA levels between the MOCs, the author focused on interviewing and making observations that would serve the author's research purpose, which was to describe how SA is created and shared within the MOCs.[2]

TIETO 2011 exercise

TIETO 2011 was a top-level Finnish exercise that concentrated on the preparedness of the nation in situations where the critical infrastuctures are threatened either naturally or through hostilities. The exercise particularly concentrated on determining the roles of the ministries, the public agencies, and the most significant private companies, such as electricity companies, maintenance companies, and ICT companies, and on developing cooperation between these parties. In the TIETO 2011 exercise, the teams were not as clearly defined in advance as in the SAR exercises. The number of organizations was also relatively high (and some organizations needed to share their work rooms with others). 18 teams were defined in total. Most of the teams had actors from only one organization. The ministries and agencies were examples of teams of this kind. However, some teams (for example, electricity companies) had actors from several organizations. The situation was more complex in the TIETO 2011 exercise than in the SAR exercises. The situation was not very predictable and the roles and procedures were quite imprecisely defined. The events and the assessment of those events also included a number of subjective judgments. Assessing the severity of the events included an interpretation that highlighted the subjectivity of SA in the TIETO 2011 exercise. The exercise lasted for two days.[2]

Interviewing method

The participants in all the cases were interviewed: in the SAR exercises, a representative of the rescue services, and in the TIETO 2011 exercise, representatives from the eight important organizations that participated in the exercise: the Ministry of Transport and Communications, the Finnish Communications Regulatory Authority, the State Security Networks Ltd., the Ministry of Defense, the Prime Minister's Office, the Defense Command, Elisa (a telecommunications and ICT service company), and the Defense Forces C4 Agency, and in the MNE 6 LOE 2, most of the members of the MOCs during the evenings after the daily experimental hours. In the interviews, the questions asked were especially what methods support the participants in creating and maintaining SA, what kind of information they would need for the creation and sharing of SA, and what or who might be the actor that would give the information to them.[2]

Observing method

The observing method focused especially on observing how the interaction occurred. In all of the cases, the method which was used was the process of observing and modeling the social contexts. The method divides the social contexts into three types, depending on the interaction types; they include informal face-to-face interaction, formal face-to-face interaction, and formal virtual interaction. Individuals form a fourth type of social context.[12]

	Informal	Formal
Face-to-face	**Informal face-to-face**	**Formal face-to-face**
Virtual	**Human agent**	**Formal virtual**

Figure 4. The social contexts were divided into three types, depending on the interaction types. Human agents form a fourth type of social context.[2]

The observing requires a team of observers because the observations need to be made in several places at the same time. In accordance with the method, the observers defined the social contexts in three steps. In the first step, the observers defined all of the social contexts in which human agents were communicating informally face to face, for example the rooms and the vehicles. In the second step, the observers focused on the larger social contexts in which two or more informal face-to-face social contexts were communicating together. In this step, the observed social contexts are usually formal face-to-face contexts and formal virtual social contexts. In the last step, the observers tried to focus on how individuals communicate in the social contexts found in the first step.[1,2]

1.5.2 Conceptual design part

The goal of the conceptual design part is to develop new conceptual solutions for COPs which support the processes of SA and SSA creation of the response organization from the design perspective of KMS. The conceptual design part consists of two research studies, which are: 1) developing a concept of a context-aware common operational picture (CACOP), 2) demonstration of the conceptual solution of a situational narrative class.

Developing a concept of a context-aware common operational picture (CACOP)

The goal was to develop a method which reduces the problems of information overload and the complexity of the situational information during a crisis situation through developing a new concept, CACOP. The main focus was on reducing the problem of information overload, while the reduction of the problem of the complexity of the situational information played a secondary role.

The research method used was a concept development based on conceptual and theoretical research and analogical reasoning. The research method consists of four steps.[3]

The first step includes the development of a conceptual model of the structures and processes of SA. This model shows how an individual actor (not nesessarily using a COP) can quickly perceive the relevant situational information in his context when creating his SA. The material was the theories of cognition shown in Chapter 2.3.[3]

The second step includes the development of a conceptual model of the structures and processes of COPs. The SHIFT concept is selected to serve as a case of the COP concept. The videos made about the usage of SHIFT during the MNE 5 campaign in 2007 are the material. Further material was the previous research about COPs and situational information, which are described in Chapter 1.3.[3]

The third step includes searching for and the definition of the analogies that exist between the conceptual model of the structures and processes of SA and the conceptual model of the structures and processes of COPs.[3]

The fourth step includes the development of the CACOP concept through adding to the COP concept the processes and structures from the conceptual model of the structures and processes of SA.[3]

Demonstration of the conceptual solution of a situational narrative class

The goal was to develop a demonstration of the conceptual solution of a situational narrative class, which is a key element in the CACOP concept, as described in Chapter 3.2.1. The demonstration was developed in a case study of critical infrastructure protection in Finland. In this case study, the situational information was the critical infrastructure failures. The material in this case study was the IFIs of three critical infrastructure sectors collected from the threat scenario-based workshops. The threat scenario was a freezing storm and a simultaneous influenza pandemic. The critical infrastructure sectors were the electricity distribution, telecommunications, and IT infrastructure companies. The IFIs were identified and documented in mind maps for each sector separately so that three mind maps were created.[4]

In this case study, the previously collected material of the three separate mind maps is analyzed together in order to combine the failures through potential IFIs. The case study includes the development of the template of the situational narrative class, which is the IFI matrix in this case, and the process of filling the IFI matrix using the previously collected material (the three mind maps).[4]

The template of the IFI matrix is based on the table of dependencies, also called the cross-impact matrix (Chai et al., 2011; Laugé et al., 2015; Luiijf et al., 2008; Mendonça and Wallace, 2006). The development of the template of the IFI matrix includes the process of creating the hierarchical terminology for the types of failures which are common to all the sectors. The terminology is divided into hierarchical levels and modified into a more consistent and commonly understandable form. In the template of the IFI matrix, all of the sectors and all of the failures are included in the first column and the first row. The rows present the causes of the failures and the columns present the potential effects of the failures. In addition, the threat scenario is included in the first rows of the first column. The columns are identical to the rows, except for the threat scenario. The potential causal relations between the failures can be marked with an 'X' in the crossing cells. In this case, the probabilities of the causal relations are not defined. The probability value is replaced with the possibility that a causal relation exists.[4]

The logic of how to fill the IFI matrix is divided into steps which start from the IFIs at the lowest level of the hierarchy of the failure types. After that, the potential causal relationships between the failures are defined at the upper level if at least one causal relation is defined between the failures at the lower level which belong to the group of detailed failures inside the failures at the upper level.[4]

1.5.3 Structure of the dissertation

This doctoral dissertation consists of a summary and four research articles. The summary has the following structure. Chapter 1, the Introduction, describes the motivation of the research and the conceptual framework, the author's background and the research environment, previous studies related to the topic, the objectives and scope of this research, and the research process. Chapter 2, Theoretical foundations, contains the theories of SA and the theories outside the research area of SA in crisis response which are utilized in this research in order to provide a better understanding of the theme of SA in crisis response. The theories outside the research area of the SA in crisis response are knowledge management and cognition. Chapter 3 consists of the results of this research, which are the analysis of the response organization from the perspective of knowledge management, the CACOP concept that was developed, and a demonstration of the conceptual solution of a situational narrative class. Chapter 4 is the discussion, which consists of the theoretical and practical implications, evaluation and validation of the methods and results of this research, and recommendations for further research.

2. Theoretical foundations

The theoretical foundations for this research consist of three theoretical sub-areas, which are: 1) situational awareness (SA) and shared situational awareness (SSA), 2) knowledge management, and 3) cognition.

2.1 Situational awareness and shared situational awareness

In a crisis response, the actors and the decision makers have to have adequate situational awareness (SA) (Endsley, 1995a; Salmon et al., 2009; Stanton et al., 2001). They should know the environment and the possibilities for action in a given situation. The term situational awareness comes from the world of the military pilot as far back as World War I. The usage of the term later reached air traffic control and the operation of large systems, such as nuclear power plants, military command, and firefighting, and other systems where the activities require dynamic updating of the situation (Endsley, 1995a). Endsley (1988) defined situational awareness as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future", which established a formal definition of situational awareness.[1,2,3]

SA is created through a continuous and cyclic process called situation assessment or, simply, the SA process. The SA process highlights the proactive nature of human cognition to continuously prepare itself to perceive the situational information that is relevant in the perceiver's context and will most probably occur in the near future. In the SA process, decision makers continuously prepare themselves for the situation at hand, act within a given environment, and perceive the information received from it and from the effects of their actions. Because the environment changes after the actions have been taken, decision makers need to continuously adapt themselves to the situation and adjust their actions to fit the situation at hand (Klein, 2009; Nofi, 2000; Smith and Hancock, 1995; Weick, 1988).[2,3]

SA is divided into three levels: 1) perception, 2) comprehension, and 3) projection (Endsley, 1995a, 2000; Endsley et al., 2003). The first level in achieving SA has to do with perceiving the relevant information in a given situation. The first SA level is the most important one for two reasons: 1) it serves as the foundation upon which the second and third levels will be constructed, and 2) most of the reasons that prevent decision makers from achieving SA are associated with the first SA level. The second SA level involves comprehending what the perceived information means when taken together. Achieving the third SA level demands expertise. A person can only achieve the third level by comprehending the situation (level 2 SA) and by understanding how the corresponding situations and the operations performed usually progress (Endsley et al., 2003).[23]

SA needs to be shared to some extent in order for the teams to be able to cooperate. SSA refers to the state in which the individuals on the team possess the same SA. However, it is important to highlight that the actors are experts who have special roles in any particular operation. Therefore, the actors rarely need their SA to be entirely shared (Endsley et al., 2003; Koskinen-Kannisto, 2013). When we are looking at team SA, it does not mean that every team member needs to have a high level of SA about everything, but they do need to have a high level of SA about the factors that are relevant for their tasks (Koskinen-Kannisto, 2013).[123]

2.2 Knowledge management: social contexts and narratives

Knowledge is distributed in social systems and it is continually regenerated in social interactions (Berger and Luckman, 1967; Dyer and Nobeoka, 2000; Nonaka et al., 2000; Nonaka and von Krogh, 2009; Tsoukas, 1996; Weick and Roberts, 1993). The social context approach highlights the idea that knowledge is always subjective and relative to the social context where the information is being processed via interactions (Geiger, 2005; Martin and Nakayama, 2010; Nonaka et al., 2000; Schreyögg and Koch, 2005). Therefore, knowledge management is increasingly considered to be a form of social context management. It focuses on the management of social contexts and the interaction between teams and between the individuals on the teams (Nonaka et al., 2000).[12]

In social context approaches, the social contexts have usually been divided into different types. Nonaka et al. (2000), who refer to social context as Ba (a Japanese word, Ba is a shared context which offers a place for knowledge creation), divided social contexts into four types: Originating Ba, Dialoguing Ba, Systemising Ba, and Exercising Ba, as shown in Figure 5. They are defined by two dimensions of interaction. One dimension has to do with the type of interaction that takes place, that is, whether the interaction takes place individually or collectively. The other dimension has to do with the media used during such interactions, that is, whether the interaction is through face-to-face contact or through virtual media such as books, manuals, e-mails, or virtual conferences. The spiral arrow (Figure 5) shows that each Ba offers a context for a specific step in the knowledge creation process (Nonaka et al., 2000).[12]

In the narrative approach, organizations are viewed as storytelling systems (Geiger, 2005). Storytelling is also one goal of context management. According to Schreyögg and Koch (2005) and also Geiger (2005), context management should enable an organization to develop social contexts that foster the construction and sharing of stories. In storytelling people create narratives. Reitsma (2010) claims that narratives create contexts; they show how independent and disconnected events come together as a whole.[2]

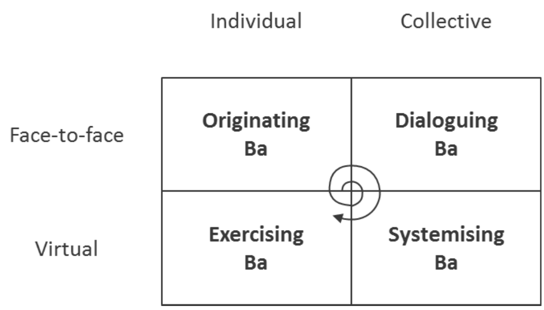

Figure 5. The social context classifications based on Nonaka et al. (2000). The spiral arrow shows that each Ba offers a context for a specific step in the knowledge creation process.[2]

The narrative approach is a particularly important part of knowledge management within organizations, which consists of small groups or teams and interaction between those teams. The size of a team can have a significant impact on storytelling because of trust and because of the shared meaning structures involved in storytelling. Narratives are important when creating and representing an identity for the team (Meyer et al., 2005; Quinn and Worline, 2008). Narratives are also essential when an organization is seeking to create SA in a changing environment (Caussanel and Soulier, 2005; Geiger, 2005; Torell, 2005). Narratives organize individual thoughts and thus help people to comprehend and communicate their experiences. Some authors claim that narratives are the most fundamental methods for making sense of experiences (Bruner, 1991; Eccles et al., 2008; Flyvbjerg, 2006).[2]

A narrative has many forms. Sequencing, either in time or thematically, forms the minimum requirement for a narrative (Meyer et al., 2005). Additionally, the elements of a narrative have many forms. The most prevalent form consists of events and reflections about experiences and interactions (Oliver and Snowden, 2005). Torell (2005) presented a narrative model that consists of eight elements: (1) agents, the people who figure in the story; (2) predicament, the problem the agents are trying to solve; (3) intentions, what the agents plan to do; (4) actions, what the agents do to achieve their intentions; (5) objects, the tools the agents will use; (6) causality, the effects (both intended and unintended) of carrying out the actions; (7) context, the many details surrounding the agents and their actions, and (8) surprises, the unexpected things that happen in the story.[2]

2.3 Cognition: two minds theory and the memory system

The human mind and mental processes are usually divided into two types, which are system 1, also called the intuitive, reflexive, old, and unconscious mind, and system 2, also called the intentional, reflective, new, and conscious mind (Evans, 2003, 2008, 2010; Kahneman, 2011; Klein, 2009; Stanovich, 2004). System 1 includes unconscious mental processes; this covers most of our mental processes. It is fast and automatic by its very nature and it does not load the working memory. System 1 works on the basis of experiences and heuristics, and it is, therefore, biased by its very nature (Kahneman, 2011; Stanovich, 2004). System 1 includes parallel processes and it is capable of handling huge amounts of information at once. However, our conscious minds only receive the final information output given by the processes, while the actual information processing takes place in the unconscious mind (Evans, 2003, 2010; Kahneman, 2011). In system 1, the knowledge is called tacit knowledge (Evans, 2010; Klein, 2009). Human brains typically try to develop in such a way that they can make most of their decisions through system 1 processes, making the decisions as automatically as possible, because system 1 is fast and energy-efficient (Baumeister and Tierney, 2012). System 2 includes conscious mental processes. It is slow, intentional, and employs language. The processes require effort for the working memory. System 2 processes are sequential and available to our conscious attention. System 2 enables us to engage in abstract and hypothetical reasoning (Evans, 2003, 2010; Kahneman, 2011), for example, to compare intentionally contrasting options for how to act in a particular situation (Klein, 2009). In system 2, the knowledge is called explicit knowledge (Evans, 2010; Klein, 2009).

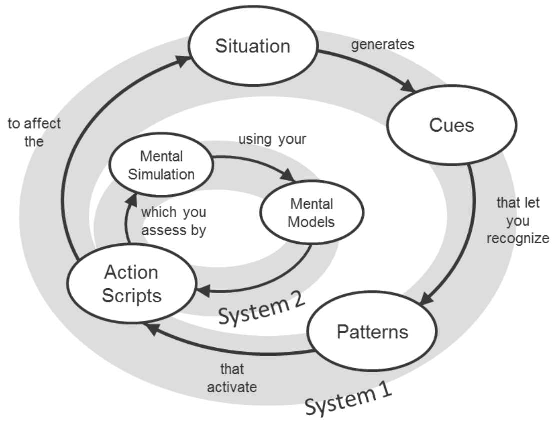

Figure 6. The recognition-Primed Decision (RPD) model based on a figure found in Klein's (2009) study and integrated with two minds theory (Evans, 2003, 2008, 2010; Kahneman, 2011; Klein, 2009; Stanovich, 2004).[2]

Decision making requires both system 1 and system 2 processes. It is always based on system 1, the unconscious, intuitive mind, while system 2, the conscious mind, has the secondary role of being an intervener if necessary. The foundational role of system 1 processes is highlighted especially when an expert with a long career and plenty of experience makes decisions under time pressure. In situations of this kind, the experts have no time to consciously generate several options and compare them in order to pick the best one (Kahneman, 2011; Klein, 2009). Instead, they intuitively use their expertise to recognize one effective option, and then they consciously evaluate and accept or correct it. Experts are capable of focusing their attention and perceiving the essential situational information intuitively (Klein, 2009).

The human memory system is traditionally divided into two main systems: working memory and long-term memory. These systems differ from each other in terms of their capacity (how much information they can store at a time) and nature (structure vs. process). Long-term memory has a huge capacity and a stable and slowly changing structure. In contrast, the working memory has a smaller capacity and a dynamic and process-like nature (Baddeley, 2012; Lewis-Peacock and Postle, 2008; Schacter, 2001). The working memory can also be defined as a temporary activation of the long-term memory (Cameron et al., 2005). Working memory is necessary for complex cognitive tasks, such as language comprehension, learning, and reasoning. It also plays a key role in shaping our consciousness (Baddeley, 2000; Cameron et al., 2005; Lewis-Peacock and Postle, 2008). According to Baddeley (2012), working memory is a complex interactive system that provides an interface between cognition and action.[3]

Working memory consists of four subsystems: the central executive, episodic buffer, visuospatial sketchpad, and phonological loop. The central executive subsystem directs a person's attention. The episodic buffer subsystem integrates information from the long-term memory and from the various subsystems of the working memory. The visuospatial sketchpad subsystem processes visual and spatial information. The phonological loop subsystem deals with the temporal dimension and the retention of sequential information such as speech (Baddeley, 2000, 2012).[3]

Long-term memory consists of procedural memory and declarative memory. Procedural memory includes tacit knowledge, such as our automatic cognitive processes and motor skills. Procedural memory is created through repeating a complex activity over and over again until the body can automatically produce the necessary action. The skill of riding a bike is an example of the content included in procedural memory.[3]

Declarative memory refers to explicit knowledge and memories that can be consciously recalled. It can be divided into two subsystems: episodic memory and semantic memory. While episodic memory allows us to consciously remember past experiences, our autobiographical memories, semantic memory refers to general knowledge that we recall without any sense of when we learned or experienced it. Through semantic memory, we can deal with concepts and facts. The structure of semantic memory can be defined as a network of concepts (Engel, 1999; Schacter, 1996, 2001; Squire et al., 1993; Tulving, 2002).[3]

One of the key features of declarative memory is that the content always includes knowledge at different levels of specificity, ranging from contextual knowledge, such as the autobiographical memories stored in our episodic memory, to abstract knowledge, such as the concepts stored in our semantic memory. Autobiographical memories are constructed from experiences using the concepts taken from semantic memory as building blocks. One example of how people create conceptual knowledge is by combining and generalizing autobiographical memories. In this way, concepts are created in our long-term memories automatically by linking autobiographical memories together and by forgetting the detailed information about the memories (Conway and Pleydell-Pearce, 2000; Schacter, 1996).[3]

3. Results

The results consist of two parts: 1) the analysis of the response organization from the perspective of knowledge management, and 2) new conceptual solutions for COPs from the perspective of KMS which reduce the problems of information overload and the complexity of the situational information described in Chapter 1.1 and which support the processes of SA and SSA creation in the response organization.

3.1 The analysis of the response organization

At first, the structure of the response organization is described through a traditional organizational chart. After that, the response organization is analyzed through the knowledge management approaches of the social contexts and narratives. Finally, the methods which support the processes of SA and SSA creation in the response organization during a crisis response are described.

The structure of the response organization can be described through Figure 7, which presents the structure of the response organization in the SAR 2010 exercise. As in the case of SAR 2010, the response organization is often a combination of integrated hierarchies and dynamic networks of teams. The integrated hierarchies consist of the organizations responsible for daily emergency situations, for example the fire and rescue actors, police, and medical actors. In smaller emergency situations, these organizations are hierarchical by nature and the communication processes are mostly vertical. In larger crises such as natural disasters, these hierarchies are often integrated through temporary management teams at several levels of the organizational hierarchy, such as the CBAO, CBSS, and CCRRS in the SAR 2010 exercise. The temporary management teams ease the horizontal and inter-organizational communication processes. Several teams which offer supporting services also join the response organization temporarily, which gives the response organization the character of a dynamic network. The supporting teams do not necessarily participate in the actual response actions, but they offer information and services needed during the response. The actors of this kind are, for example the police, aviation authorities, border guards, and volunteers. In the SAR 2010 exercise, these teams were managed by the management team of CBSS. Some supporting teams join the response organization only during the period when a particular supporting service is needed (Baris, 2009; Klein, 2009; Rimstad et al., 2014; Römer et al., 2014; Schraagen et al., 2010; Simpson et al., 2008; Uhr et al., 2008; Wex et al., 2014; Wolbers and Boersma, 2013).[1 2 3]

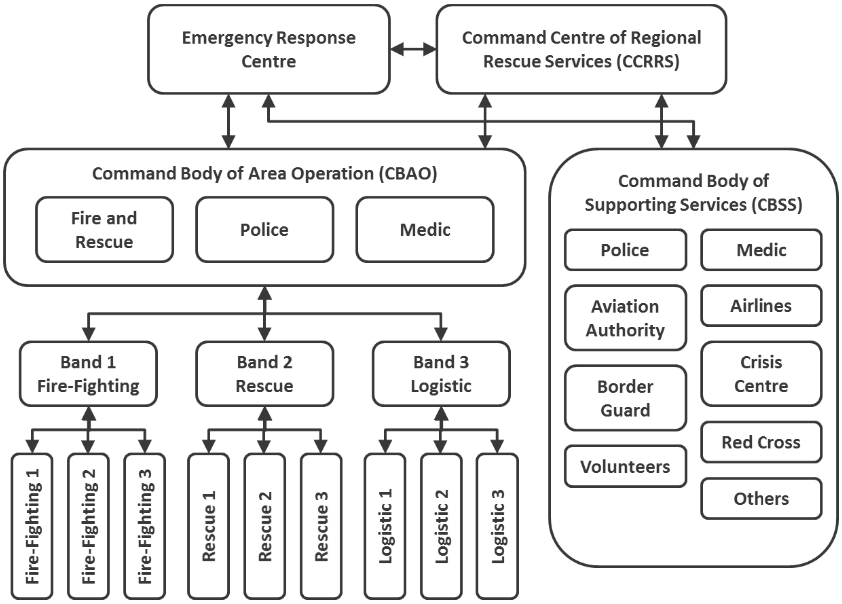

Figure 7. The organizational structure in the SAR 2010 exercise.[2]

When the response organization is being analyzed and described through the knowledge management approach of the social contexts, the response organization is a social system, where SA is always subjective and relative to the social context. Social contexts are the platform of the creation and sharing of SA. In other words, SA is continually regenerated in the interactions of social contexts in a decentralized manner. Social contexts arise from the interaction and the type of the interaction defines the type of social context. The response organizations consist of four types of social contexts, which are informal face-to-face, formal face-to-face, formal virtual, and human agents.[1 2 3]

The social contexts can include actors from one organization, such as police officers on patrol, or actors from several organizations or institutions, which is typical in the social contexts related to management teams. For example, the response organization in the SAR 2009 exercise can be considered a system of social contexts, as shown in Figure 8. In the SAR 2009 exercise, all of the social contexts had special roles in the social system they formed. The response actors' SA in a certain social context differed considerably from other response actors' SA in another social context. For example, when the rescue boats and helicopters were focusing on searching for and rescuing the victims, the police cars focused on isolating the harbor where the victims were going to be landed and on tunneling routes from the harbor to several hospitals. The CBAO focused on coordinating the search and rescue operations and the CBSS concentrated on managing the actors who were offering supporting services, such as psychological support, to the patients and victims' families. At the head of the whole system, the CCRRS focused on directing all of these social contexts and on informing the media about the progress of the situation.[1 2]

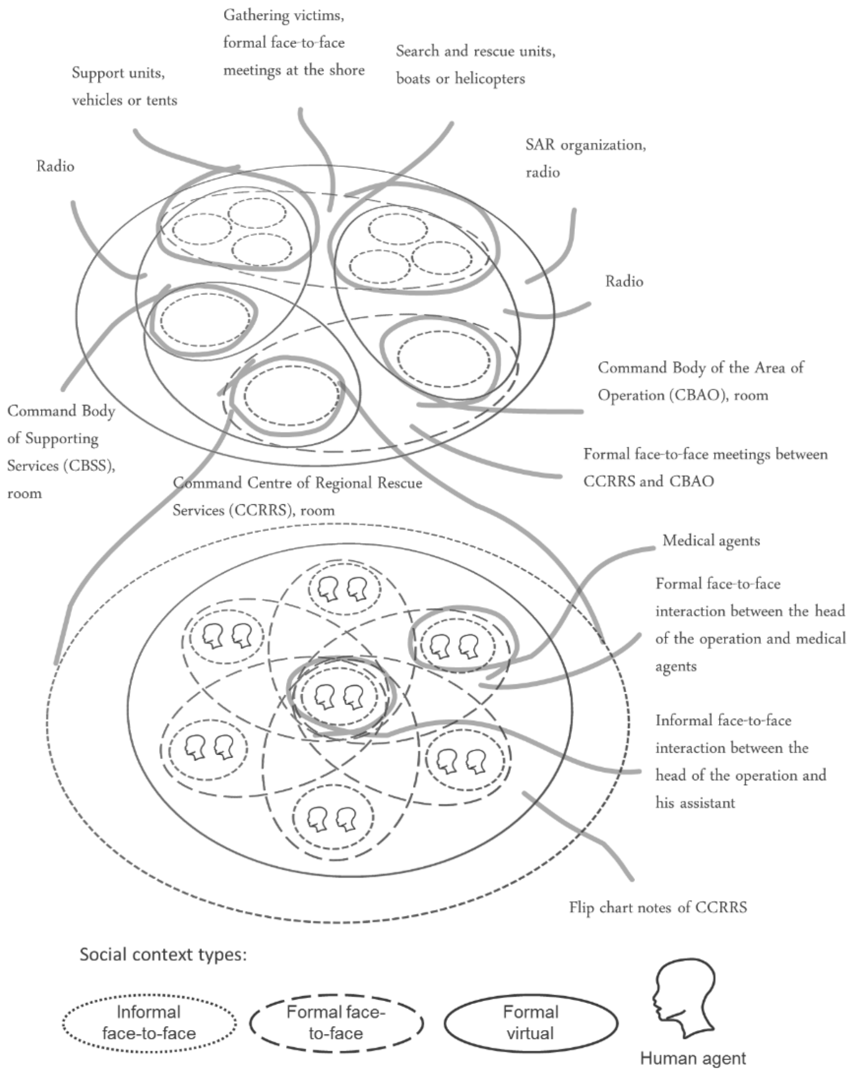

Figure 8. The response organization of SAR 2009 presented as a system of social contexts – the whole system above and the CCRRS below.[1]

Taking into account the knowledge management approach of narratives, the response organization is a social system, where SA is always subjective and relative to the social context, and SA is created in the form of a situational narrative. Social contexts are the platform of situational narrative creation and sharing. In other words, situational narratives are continually regenerated in the interactions of social contexts in a decentralized manner.[23]

Situational narratives support the response actors in achieving all the levels of SA and sharing SA. They support the response actors in achieving the first SA level, directing their attention towards the elements of situational information that are relevant in their context. The creation of the situational narratives supports the actors in achieving the second SA level by combining the elements of situational information through causal relations. Situational narratives also make it easier to convert the tacit form of SA into an explicit form and in this way to share SA (Luokkala and Virrantaus, 2014).[2,3]

Situational narratives consist of Torell's (2005) narrative elements: (1) Agents, (2) Predicament, (3) Intentions, (4) Actions, (5) Objects, (6) Causality, (7) Context, and (8) Surprises. For example, in the SAR 2009 exercise, the potential agents/actors (1) were the SAR units of the Finnish Border Guard, the voluntary maritime rescue units of the Finnish Lifeboat Institution, and Navy units. Second, the CBAO also needed to understand the problems pertaining to the situation. In the SAR 2009 exercise, the CBAO needed to know (2) where the plane had crash-landed, how many people were in the plane, and whether or not the plane contained matter or stuff that would be dangerous to the environment. The CBAO also needed to know (3) the intentions of the units and (4) the actions and achievements of the units in order to coordinate them effectively. It was also important to know (5) what kinds of vessels and helicopters were available in order to figure out how to carry out the systematic search operation for the victims and how to rescue them from the sea and to transport them to hospitals. In order to understand the progression of the situation, the CBAO needed to construct (6) causal relations between the events and actions during the operation. The CBAO also needed to know the context of the accident. It is important, for example, to know (7) what the weather was like and the sea temperature, how far from the plane the victims could drift in the water, and how long they could stay alive in the cold water. Sometimes, but not always, unexpected things might occur in the situation. In the SAR 2009 exercise, a good example of an unexpected thing emerged when rescue personnel suspected that (8) the plane had crash-landed on top of a pipe under the surface of the sea.[2]

The individual response actor's situational narrative creation and sharing is presented as a part of the conceptual model of the structures and processes of SA (Luokkala et al., 2016). In this model, the individual response actor's SA creation consists of two cyclic processes taking place in two cognitive systems: the process of perception in system 1 and the process of situational narrative creation in system 2, which are presented in Figure 9. The third process in Figure 9, which is the learning process in system 1, is not related to the actual SA creation process but the process of developing the actor's expertise through the repeated situational narrative creation processes. The general pattern is that when an individual response actor has created a large number of sufficiently similar context-related situational narratives in several situations, they will be unconsciously merged in his memory system, and new general, context-free knowledge or a situational narrative schema/concept will be created.[3]

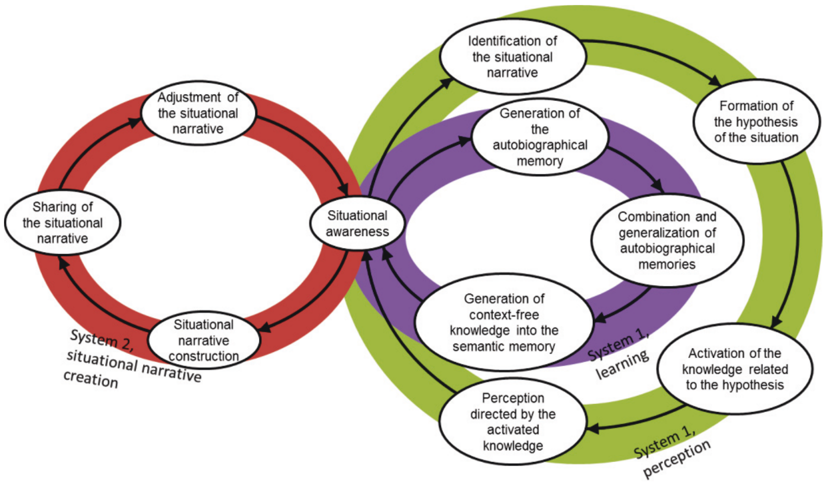

Figure 9. Individual SA process.

In the process of perception (Figure 9) (the first SA level), the individual response actor unconsciously prepares for the forthcoming information on the basis of his expertise and his current SA. The consciously (in system 2) created situational narrative will be identified as an unfinished instance of some general situational narrative schema/concept which is learned (in a learning process) from previous situations. The activation of that hypothesis of the situation directs the attention of subsequent perception. The individual response actor perceives the information which satisfies the activated hypothesis faster than other available information. The information which does not satisfy the activated hypothesis will often be missed, even though it would be easy to perceive, unless it is exceptionally striking information which it is always relevant to perceive.[3]

The process of situational narrative creation (the second SA level) enables an individual response actor to convert his SA from a tacit to an explicit form, and so to share that SA in the social context in order to adjust it to fulfill the expectations of the other response actors who belong to the same social context through interaction. In the situational narrative creation process, an individual actor balances internal and external expectations. The situational narrative should fulfill both the individual actor's own expectations (to be consistent with his earlier experiments/hypothesis of the situation) and the expectations of other actors in the same social context.[3]

It is not only individual response actors who create SA in the form of situational narrative, but also groups/teams too. More precisely, individual response actors share their SA in a social context and in this way create SSA. When the form of SA is a situational narrative, SSA is considered as a shared situational narrative. The processes of situational narrative creation and sharing can be described through Figure 9 and Figure 10.

In the same way as in the process of the individual response actor's situational narrative creation, the process of shared situational narrative creation also starts from perception (the first SA level). Figure 10 shows that the situational information which is included into the shared situational narrative comes from both inside and outside the social context where the shared situational narrative is created. The inside information comes from the individual member's SA, whereas the outside information comes from other social contexts. Both types of input information come in the form of a situational narrative, but they appear in different kinds of interactions. Referring to social context management theories (Seppänen et al., 2013), the situational narratives that come from inside the social context appear as informal face-to-face interactions (for example, the informal discussions in a management team, such as CCRRS in the SAR 2010 exercise), formal face-to-face interactions (for example, formal/structured discussions in a management team, such as CCRRS in the SAR 2010 exercise), and formal virtual types of interaction (for example, the list of events/event diary in a management team, such as CCRRS in the SAR 2010 exercise), whereas the narratives that come from outside the social context appear as formal face-to-face interactions (reporting events between the management teams, such as CCRRS, CBAO, and CBSS in the SAR 2010 exercise) and formal virtual types of interaction (for example, virtual meetings and information sharing tools included in the COP systems).[2]

At the second SA level, the social context needs to comprehend the information that has been received in relation to its goals and tasks. In other words, the members of a particular social context need to jointly comprehend the received information in relation to the goals and the task of the social context. This is a process which combines several individual situational narrative creation processes shown in Figure 9. The processes combine with each other through the part "sharing of the situational narrative".[2]

The situational narrative creation and sharing processes are supported through two kinds of methods, which are map systems and the traditional lists of events (event diaries). The need for these systems comes from the spatio-temporal nature of situational information. Maps are usually included in the modern COP systems and they support the response actors in managing the spatial dimension of situational information. In contrast, the lists of events are relatively traditional, such as whiteboards, and they support the response actors in managing the temporal dimension of the situational information, such as the sequence of the events.[2]

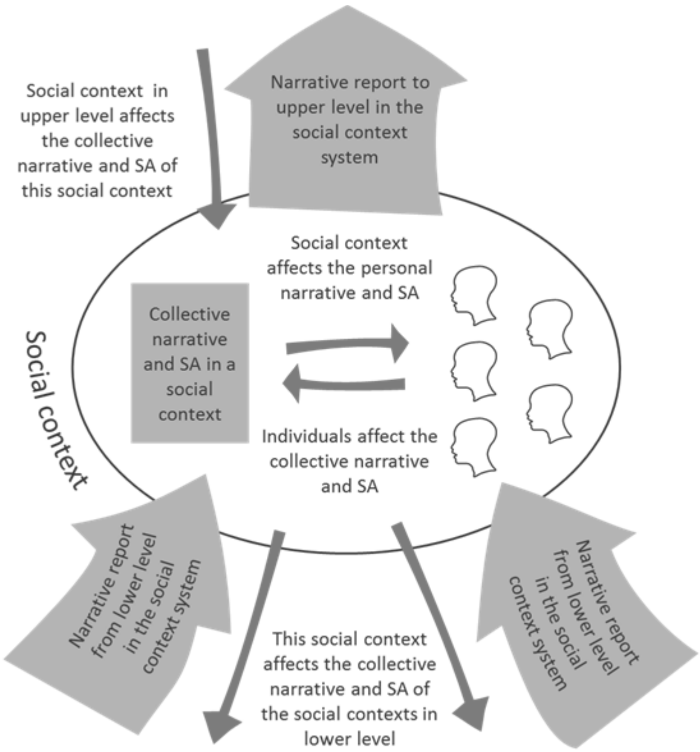

Figure 10. Social context situational narrative creation and sharing.[2]

Maps are usually included in modern COP systems. A COP is an information system which enables the situational information to be produced, shared, and visually presented in such a way that all the situational information is available to all of the actors involved in the response organization in as real-time a manner as possible. When situational information is processed through the COP systems, situational information means instances which are linked to predefined classes. Classes define which attribute information can be added to an instance. Attributes typically include the location and the time of the instance, as well as the qualitative information on the instance. For example, if the instance is an incident, the qualitative information can be the size of the incident, the number of victims of the incident, and the area affected by the incident. In COP systems the instances are visualized on a static base map. Attributes can also include information on how the instance is visualized on the base map, in other words through which pictogram. One example of a map-based COP system is the concept of SHIFT, which was used in the MNE 5 experiment (Figure 2).[3]

Alongside the map systems, situational narrative creation and sharing is supported through the traditional method of lists of events (event diaries). Lists of events show the temporal dimension of the instances, such as the chronology. Lists of events are such important methods in situational narrative creation that they are usually positioned in such a way that every member of the team can see the list during the operation. This was seemingly important, especially in the

MNE 6 LOE 2 case, where the actors in the MOCs did not know each other beforehand and had different mother tongues (they spoke English in the MOCs). The lists of events made it easier to refer to the events or to other issues when needed in discussions and they made the discussions in the MOCs clearly more effortless.[2]

3.2 New conceptual solutions for COP design

The second result is the new conceptual solutions for COP design from the perspective of KMS which support the processes of SA and SSA creation in the response organization. The new solutions reduce the problems of information overload and the complexity of the situational information defined in Chapter 1.1. The solutions are the CACOP concept and the conceptual prototype of the situational narrative class.

3.2.1 The CACOP concept

The CACOP concept reduces both the problem of information overload and the complexity of the situational information. The conceptual architecture of CACOP (Figure 11) has been developed through adding the Situational narrative view and the semantic and episodic databases to the COP concept. The Situational narrative view enables the CACOP user to create situational narratives through combining the instances on the basis of their assumed causal relationships. Situational narratives reduce the problem of the complexity of the situational information and enable the CACOP user to achieve the second and the third SA levels. The causal relationships are deduced by the CACOP user himself on the basis of the attribute information of the instances and the spatial and temporal distances between the instances. The possibility of creating situational narratives enables two things to happen. First, the CACOP user can convert the tacit form of SA into an explicit form, which can be shared more easily in the social context. For example, the user can report the situational narrative he has created to the management team at the upper organizational level. Second, when the CACOP users have created a large number of situational narratives, the situational narratives can be combined and situational narrative classes can be created. The concept of a situational narrative class is the key factor which makes possible the visualization process, which reduces the problem of information overload by highlighting the instances which are relevant for the CACOP user in his context. In the CACOP concept, the episodic database saves the situational narratives (in addition to the instances) and the semantic database saves the situational narrative classes (in addition to the instance classes), as shown in Figure 11.[3]

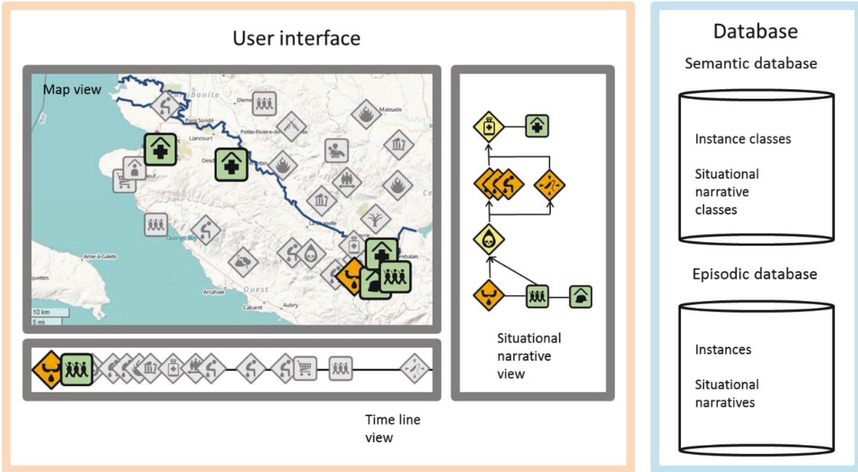

Figure 11. The conceptual architecture of CACOP consists of the user interface and the database. The user interface includes the map view, the time line view, and the situational narrative view. The database includes the semantic database where the instance classes and situational narrative classes are saved and the episodic database, which includes the instances and situational narratives.[3]

In the same way as in the conceptual model of the structures and processes of SA (Figure 9), the processes of the CACOP concept are divided into two kinds of processes: automatic processes (system 1) and manual processes (system 2), as shown in Figure 11. System 1 includes the automatic cyclic processes, which are the learning process (light purple) and the visualization process (light olive green). The CACOP user is not conscious of these processes and the processes do not load his working memory. System 2 includes the manual processes of situational narrative creation (light red) and the instance creation (light blue) taking place in the Situational narrative view.[3]

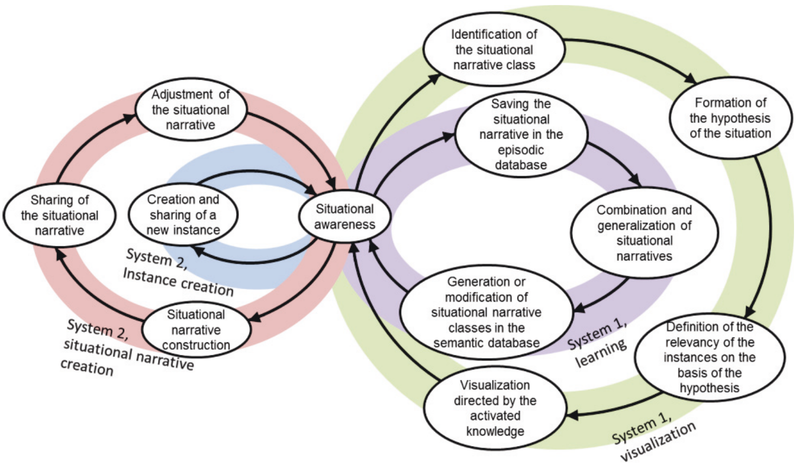

Figure 12. The processes of the CACOP concept are divided into two kinds of processes: automatic processes (system 1) and manual processes (system 2).[3]

The learning process (Figure 12) adds situational narrative classes to the semantic database by combining several sufficiently similar situational narratives (Figure 13). In the first step of the process, the system saves the newly finished situational narrative (created by the CACOP user in the Situational narrative view) into the episodic database. In the episodic database, the situational narratives consist of the instances and the causal relations which link the instances together. Because the instances have locations in the spatial and temporal dimensions, the causally linked instances have distances in the spatial and temporal dimensions, which enables situational narrative classes to be produced. In the second step, the system starts to modify the content of the semantic database on the basis of the newly saved situational narrative. The system identifies the situational narrative class which the new situational narrative belongs to as an instance, and modifies the identified situational narrative class on the basis of the new situational narrative. The system can identify the situational narrative as being an instance of a situational narrative class, for example, on the basis of the correspondence of the instances included in the situational narrative and the instance classes included in the situational narrative classes. In the third step of the learning process, the system saves the modified or new situational narrative class into the semantic database. The situational narrative classes can then be utilized in the visualization process.[3]

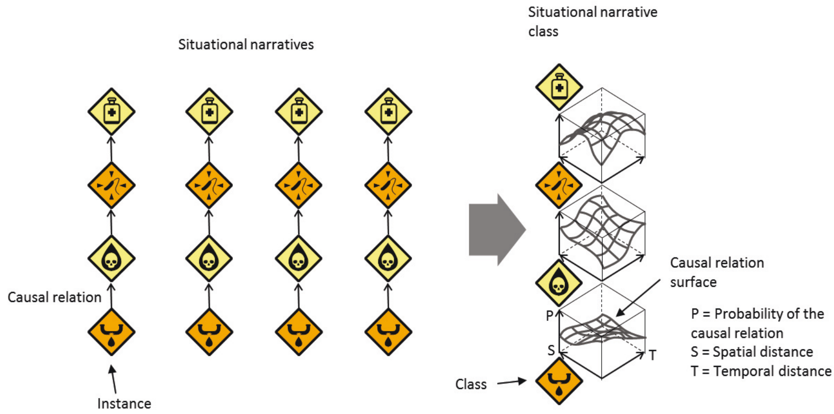

Figure 13. A situational narrative class is created from several sufficiently similar situational narratives.[3]

In the visualization process (Figure 12), the CACOP system prepares to define which instances will be relevant to the CACOP user on the basis of the unfinished situational narrative and the corresponding situational narrative classes. In this way the system can visualize the instances shown in the CACOP user interface, highlighting the relevant instances and enabling the CACOP user to perceive the relevant instances in a shorter time.[3]

In the first step of the visualization process, the system identifies the unfinished situational narrative (constructed by the user) as potentially being an instance of one or more situational narrative classes saved in the semantic database. In contrast to the learning process, in which the identification of the situational narrative starts only after the situational narrative is finished, in the visualization process, the identification starts every time the user adds a new instance to the unfinished situational narrative. The system can identify the situational narrative as being an instance of a situational narrative class, for example, on the basis of the partial correspondence of the instances included in the situational narrative and the instance classes included in the situational narrative class.[3]

In the third step, the system defines the probability of each instance shown in the CACOP user interface taking place in the unfinished situational narrative. As Figure 13 shows, the probabilities are defined on the basis of the spatial (S) and temporal (T) distances between the instances and the probabilities (P) of the causal relations in the corresponding distances on the causal relation surface between the corresponding instance classes in the situational narrative class.[3]

In the fourth step, the system visualizes the instances on the basis of the defined probabilities. The visualization can be created, for example, through changing the size or color brightness of the pictographic symbols of the instances, as in Figure 11. After the visualization, it will be easier for the CACOP user to perceive the instances which are relevant for him.[3]

System 2 includes two processes, which are the instance creation process and the situational narrative creation process. These are manual and cyclic processes. In the instance creation process, the CACOP user creates and shares a new instance. The instance is created by linking a perception obtained from the environment to the instance class and adding the spatial and temporal location and other attribute information to it.[3]

In the situational narrative creation process, the CACOP user creates a situational narrative in the Situational narrative view and shares a new situational narrative with other CACOP users involved in the crisis response. In order to work properly, the system needs to have been used in several earlier crises, as a result of which a large number of situational narratives have been created and situational narrative classes have been added to the semantic database. In the first step of the process, the CACOP user starts creating the situational narrative by selecting the instances from the Map view or Timeline view and linking them through the causal relations he has assumed. The ability of the CACOP user to perceive and select the instances which form the situational narrative has been increased through the visualization process. In the second step, the CACOP user shares the unfinished situational narrative with other actors in the crisis response organization, as stated also in the description of a response organization in Chapter 3.1. In this way, the user tests the validity of the situational narrative. The situational narrative needs to be formed in interaction with other actors in the crisis response organization, which ensures that the situational narrative fulfills the expectations of the other actors, as well as the actor's own expectations. In the third step, the CACOP user gets feedback that helps him to modify the situational narrative. The modification can include the adding of extra instances to the situational narrative or the removal of instances which are assumed not to be a part of the situational narrative.[3]

3.2.2 Demonstration of the conceptual solution of a situational narrative class

A demonstration of the conceptual solution of a situational narrative class is developed in the case study of the critical infrastructure protection in Finland. In this case study, the situational narrative class is implemented as an IFI matrix (infrastructure failure interdependencies) where the situational information interdependencies are called IFIs.

In the case study, the previously collected material in the three separate mind maps which include information about the potential failures in each sector of critical infrastructures is analyzed together in order to combine the failures through potential IFIs. The case study includes the development of the template of the IFI matrix and the process of filling the IFI matrix using the previously collected material described in Chapter 1.5.2.

Figure 14 shows a part of the template of the IFI matrix that was developed. The template of the IFI matrix includes the hierarchical levels of the failure types consisting of the critical infrastructure sectors: the electricity distribution, telecommunications, and IT infrastructure companies, the three types of upper-level failure types common to all the three sectors: the failures of physical structures, the failures of service production, and the failures of maintenance, and the lower-level failures, which are the sector-specific detail failures inside the three upper-level failure types. The detailed failure types are partly similar for all of the sectors but the sector-specific terminology has also been included at the lower level.[4]

The process of filling the IFI matrix started from the filling of the lower-level IFIs, for example the IFI between Failure 1.1.1: “Failure in medium-voltage network” and Failure 1.2.1: “Failure in electricity distribution” in Figure 14. After that, the potential causal relations between the instances at the upper level in the instance hierarchy are defined if at least one causal relation is defined between lower-level instances. For example, in the IFI matrix presented in Figure 14, the potential causal relation has been defined between Failure 1.1: “Failure in structures” of the electric power distribution sector and Failure 1.2: “Failure in services” of the electric power distribution sector because the causal relation has been defined between Failure 1.1.1 and Failure 1.2.1 in the previous step.[4]

Failures / Cause failures	Potential effect failure	Sector 1	Failure 1.1	Failure 1.1.1	Failure 1.1.2	Failure 1.2	Failure 1.2.1	Failure 1.2.2	Failure 1.2.3	Failure 1.3	Failure 1.3.1	Failure 1.3.2	Failure 1.3.3	Sector 2	Failure 2.1	Failure 2.1.1	Failure 2.1.2
Scenario: Storm			X														
Strong winds				X													
Pilling of ice				X													
Falling trees				X													
Sector 1: Electric power distribution																	
Failure in structures 1.1						X											
Failure 1.1.1: Failure in medium voltage network							X										
Failure 1.1.2: Failure in low voltage network																	
Failure in services 1.2															X		
Failure 1.2.1: Failure in electricity distribution																X	X
Failure 1.2.2: Failure in customer service																	
Failure 1.2.3: Failure in availability of competence																	
Failure in maintenance 1.3																	
Failure 1.3.1: Failure in monitoring and fault-finding																	
Failure 1.3.2: Failure in repair work																	
Failure 1.3.3: Failure in availability of spare parts																	
Sector 2: Information and telecommunication																	
Failure in structures 2.1																	
Failure 2.1.1																	
Failure 2.1.2																	

Figure 14. The IFI matrix as a prototype of the situational narrative class; specific descriptions are not included because of space limitations and for reasons of confidentiality.[4]

The cross-sector IFIs are usually defined in such a way that a service failure in one sector causes a failure (in structures or in maintenance) in another sector. For example, a causal relation has been defined between Failure 1.2.1: “Failure in electricity distribution” and Failure 2.1.1. In situations where the detailed information about the failures or IFIs is classified/sensitive, it is possible to define the cross-sector IFIs only at the upper level of the instance type hierarchy, for example between Failure 1.2 and Failure 2.1 in Figure 14.[4]

The filled IFI matrix includes the potential causal relations between the failures. In addition, the indirect causal relations and the potential situational narratives can also be derived from the IFI matrix. For example, the following situational narrative can be derived from the IFI matrix: Failure 1.1.1: "Failure in medium voltage network" causes Failure 1.2.1: "Failure in electricity distribution", which causes Failure 2.1.1, which causes Failure 2.2.1, which causes Failure 1.3.1: "Failure in repair work", which again causes Failure 1.1.1: "Failure in medium-voltage network" as illustrated in Figure 15.

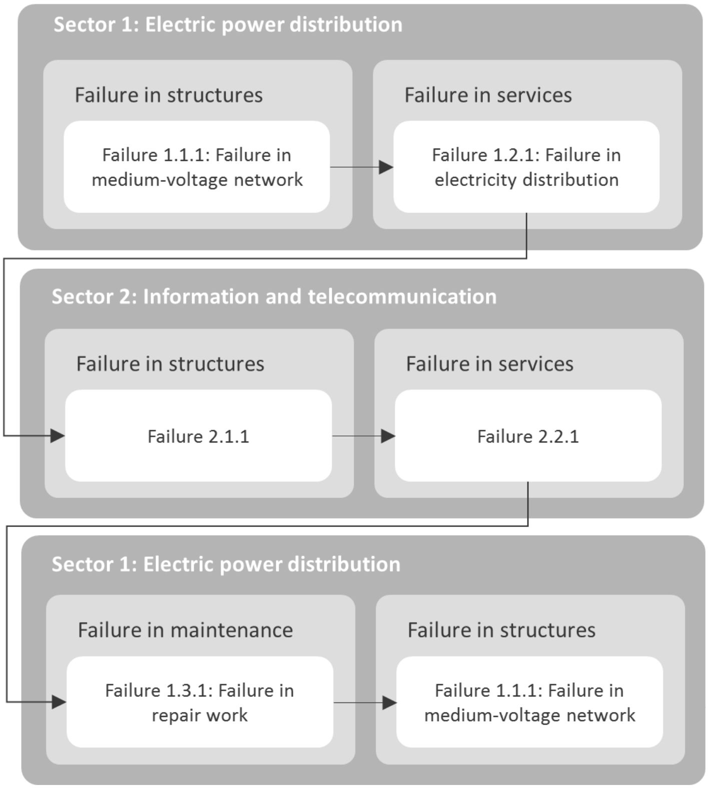

Figure 15. Situational narratives can be derived from the IFI matrix (Figure 14).

When the IFI matrix is considered as a situational narrative class, the failure types correspond to the instance classes. As described in Chapter 3.2.1 and in Figure 8, the semantic database of the CACOP concept consists of the instance classes and the situational narrative classes. In the case study, the semantic database includes the failure types and the semantic relations between them. The semantic relations come from the hierarchy of the failure types: the three types of upper-level failure types common to all the three sectors: the failures of physical structures, the failures of service production, and the failures of maintenance, and the lower-level failures, which are the sector-specific detail failures inside the three upper-level failure types. In addition, the semantic database includes the situational narrative classes, which in this case study are the IFI matrix, which is built from the failure types and filled with the potential causal relations between the failure types, and other corresponding matrices. The causal relation surfaces are not defined in the case study, but they have been replaced by using 'X', which indicates that a certain failure has potentially caused another failure.

Applying the CACOP concept in the response to a situation corresponding to the scenario of the case study described in Chapter 1.5.2, the unfinished situational narrative created by the CACOP user can be automatically identified as being an instance of the IFI matrix. The identification can be made if the failures/instances and the defined causal relations in the unfinished situational narrative correspond to the failure types and the IFIs in the IFI matrix. After the unfinished situational narrative is identified as being an instance of the IFI matrix, a visualization of the failures/instances can be made, highlighting the failures/instances which are most probably included in the situational narrative the CACOP user is constructing.

4. Discussion

4.1 Theoretical implications

This research contributes to the existing scientific discussion about SA and COPs in crisis response through describing the response organization from the perspective of knowledge management, and through developing new methods and concepts for COP design that fill the gap in the current research described in Chapter 1.3.2 and take into account the design propositions described in Chapter 1.3.3.

In the analysis and the description of the response organization from the perspective of knowledge management, the existing understanding about the response organization described in Chapter 1.3.1 and the models of SA creation described in Chapter 2.1 are enriched by using concepts which had not been used in this context earlier. The most important new concepts are the concepts of the social context and the situational narrative presented in Chapter 2.2. These new concepts provide a better starting point for taking into consideration the features of the response as actions taken by several organizations and teams and the decentralized and distributed nature of management during the response, as described in Chapter 1.1. In addition, this research combines the theories of two minds, presented in Chapter 2.3, and SA, presented in Chapter 2.1. This is a valuable theoretical contribution which enables one to understand the conscious and unconscious sides of SA creation and the tacit and explicit sides of SA. An understanding of these sides is vital in order to take the perspective of knowledge management when studying the features of the response organization. The result of the descriptive part, which is a description of the response organization from the perspective of knowledge management, answers the first research question.

The contributions to the literature on the design of COP systems are also significant. The CACOP concept follows the trends and recommendations of COP development (Turoff et al., 2004; Vescoukis et al., 2012; Dorasamy et al., 2013) as it supports the knowledge management processes of the crisis response organization in a comprehensive way. CACOP supports knowledge creation, storage, and reuse processes. It provides the situational narrative classes as a shared knowledge space with the use of a consistent and well-defined vocabulary (in CACOP, the instance classes). It uses situational narratives to model and explicitly represent knowledge. It permits collaborative efforts between employees as it includes the process of the creation and sharing of situational narratives.

CACOP also utilizes and reuses the stored knowledge in the visualization process, which is based on situational narratives and situational narrative classes.

Through the CACOP concept that was developed, this research also contributes to the scientific literature which focuses on filtering methods that aim to reduce the problem of information overload. In this research branch, the CACOP concept is a new approach. No other articles which present filtering methods which automatically define the relevance of instances on the basis of the situational narrative have been found. In contrast to the manual filtering in SHIFT (Vesterinen, 2008) and PIE (Kamel Boulos et al., 2011), which defines the relevance of instances on the basis of a role of the user defined beforehand, or a manually adjusted relevancy score of the instances, the CACOP concept automatically identifies the context where the user is gaining his SA, and on the basis of that context it defines the importance of the instances which are available for the CACOP user. This is a significant contribution, assuming that the amount of situational information available in crises will grow wildly in the future because of technological developments, causing an increase in the problem of information overload. It would also be possible to combine the features that form the CACOP concept with existing systems, such as PIE. Combinations of this kind would produce effective results in the reduction of information overload.

The concept of the situational narrative class and the IFI matrix contributes to the scientific discussion about the methods which reduce the problems related to the usage of COPs in crisis response. As in crisis response, a large number of the elements of situational information are created and shared by several organizations through COP systems, the IFI matrix can support the COP user in comprehending the situational information interdependencies, especially the cross-sector situational information interdependencies; the interdependencies between the elements of situational information created by several organizations. The IFI matrix can support the COP user in avoiding the problem of the complexity of the situational information and in this way achieving the second SA level.

From the methods published earlier, the online questionnaire method described by Laugé et al. (2015) is the most similar to and most comparable with the IFI matrix method. However, Laugé et al. (2015) consider the critical infrastructures as monolithic entities and their results offer general-level information about the infrastructure failure interdependencies, but no detailed information, such as which parts of the critical infrastructure would fail because of failures in some other parts of the critical infrastructure. Compared with the method described by Laugé et al. (2015), the IFI matrix is designed to identify infrastructure failure interdependencies in a more detailed way. In addition to the protection of critical infrastructure, the IFI matrix is generalized to be a method for identifying the situational information interdependencies. This is a valuable contribution to the discussion about the reduction of the complexity of the situational information in COP usage in crisis response.

4.2 Practical implications

This research is implemented in connection with real organizations responsible for response actions during crises, as described in Chapter 1.2 and Chapter 1.5. In addition to the research problems and the goals of this research being based on scientific discussion and literature, the problems and goals of this research have been defined together with real crisis response organizations. Therefore, the results of this research are valuable in real crisis management activities.

The analysis and the description of the response organization from the perspective of knowledge management, consisting of the concepts of the social context and the situational narrative, offer a new approach to managing the SA creation processes in the response organization. This approach enables the response managers to comprehend the decentralized and distributed features of the SA creation processes. In practice, through internalizing this approach, the managers of the response organization could observe the different social contexts and the processes of situational narrative creation and sharing in practice. Through becoming capable of observing the different social contexts and the processes of situational narrative creation and sharing in practice, the managers also become capable of modifying the social contexts and managing the processes of situational narrative creation and sharing.

The CACOP concept has been developed in order to reduce the negative causes of information overload. The concept is especially valuable in crisis responses where several actors constitute a temporary crisis response organization, they have a large amount of situational information available, and they have only a limited amount of time in which to perceive the relevant parts of the available situational information. In crisis responses of this kind, CACOP eases and speeds up the ability of the actors in a crisis response situation to perceive the situational information that is relevant in their context. In addition to the problem of information overload, the CACOP concept reduces the problem of the complexity of the situation. CACOP enables the user to create situational narratives through combining the instances shared in CACOP. Situational narratives can be utilized in the achievement of the second SA level and in the creation of SSA in social contexts. The CACOP concept, together with the IFI matrix, gives an answer to the second research question. When implemented as a real system, CACOP has the potential to speed up the operations and therefore reduce the negative effects of crises, such as the numbers of victims and levels of economic losses. However, this is still a hypothesis which needs to be tested in future.

The IFI matrix can potentially reduce the problems of information overload and the complexity of the situational information and support COP users in achieving the first and the second SA level in real crisis situations. The IFI matrix can be utilized in the implementation of CACOP as a demonstration of the situational narrative class. In addition, the users of any COP systems can utilize the IFI matrix in order to comprehend how the elements of situational information are related and how they constitute an overall picture of the situation when put together. This has not been tested and validated in any case studies. Therefore, the validation is performed by using the case studies as material in the subsequent process of deductive reasoning. In the SAR 2009 exercise, MNE

6 LOE 2 campaign, and TIETO 2011 exercise presented in Chapter 1.5.1, the temporary response organization consisted of several organizations which do not cooperate actively outside crises, and all of the organizations were producers of situational information. It can be assumed that these conditions in the cases caused the problem of the complexity of the situational information. As the IFI matrix supports the response actors in comprehending the situational information interdependencies and in this way reduces the problem of the complexity of the situational information, the IFI matrix would have been a useful method for the actors in the SAR 2009 exercise, MNE 6 LOE 2 campaign, and TIETO 2011 exercise. It can be expected that the IFI matrix would have been an especially valuable method in the TIETO 2011 exercise, and would be valuable in similar crises because of the relatively high number of organizations involved in the temporary response organization and the complexity of the situation. The IFI matrix gives a part of the answer to the second research question. When using the IFI matrix in a crisis response, the response organization would have the potential to speed up its operations and therefore reduce the negative effects of crises, such as the numbers of victims and levels of economic losses.

4.3 Reliability and validity

The assessment of the reliability and validity of the descriptive part of this research includes the analysis of construct validity described by Yin (2009). Construct validity indicates the process of identifying correct operational measures for the concepts being studied. The measures of the construct validity were the types of interaction and methods used in order to support the response actors in creating SA, the types of information the response actors would need for the creation of SA, and the connections of the response actors with the other response actors. Two tactics are utilized to increase the construct validity when doing case studies: the use of multiple sources of evidence and to have the draft case study report reviewed by key informants.

The tactic of the use of multiple sources is used in three ways. First, the description of the response organization is based on both literature research and the data collection methods in the case studies, as described in Chapter 1.5.1. Second, the data were collected from four case studies. Third, the data were collected using two methods: the interviewing method and the observing method. These methods have strengths and weaknesses. When taken together, the weaknesses of one method are eliminated by the strengths of the other method. The interviewing method expanded the perspective. The interviews were especially important in the TIETO 2011 scenario, where the organization was much larger than in the other cases. The interviews turned out to be useful for clarifying how actors usually support SA creation and maintenance. It was more difficult for the interviewees to know what kind of information they would need in SA creation and sharing and what or who the actor giving them the information would be. Therefore, it was vital to be present during the cases and to observe the types of social contexts on the spot. The method of observing different types of social contexts made it easier to observe how the actors interacted during the case studies. The method was also problematic because it does not take into account that the organization being observed and the interactions inside it may change during the operations. The most important method was participating in the case studies as observers. Many of the relevant data were also obtained during the cases by listening to the discussions that took place, for example during the lunch and coffee breaks; in the MNE 6 LOE 2 scenario, data were also obtained during the evenings when the author spent time with those participating in the exercise.

The tactic of having the draft case study report reviewed by key informants is used in the after-action reviews organized after the case studies. In the after-action reviews, the data that had been collected and the preliminary conclusions drawn on the basis of those data were presented. The participants in the case studies had the opportunity to comment on and criticize the preliminary conclusions drawn on the basis of the data that had been collected. The method of graphically modeling the different types of social contexts proved to be useful in the after-action reviews. A limitation of the method is that communication is modeled as static social contexts. Therefore, the communication is modeled as it occurs at a particular moment in the situation, even though the situation changes during the operation. Another limitation is that the activity level of the communication processes is not shown in the social context model. Therefore, all social contexts seem to be equally important in the graphic model, which may cause misunderstandings.

The method used in the development of the CACOP concept is analogical reasoning. A conceptual model of the structures and processes of SA has been developed and an analogy has been made between the conceptual model of the structures and processes of SA and the conceptual model of the structures and processes of COPs in order to develop the CACOP concept. This analogy is made in order to imitate the properties of human cognition, which has developed in human beings over the course of thousands of years through evolution and which helps human beings to reduce the problem of information overload. In this way, the features of human cognition which enable human beings to be continuously prepared to perceive the relevant information from their environment have been imitated.

In this research, the CACOP concept was developed on the foundations of the SHIFT concept. Another option was to investigate several COP systems, define their common features, and then form a conceptual model of the structures and processes of a traditional COP. Instead of that, the SHIFT concept was selected to be the case in this research because we had an opportunity to observe the use of SHIFT both directly on the spot and afterwards on videos filmed during the MNE5 campaign.

4.4 Recommendations for further research and development

In this research, the response actors are considered experts, except for the situational information producers, who also include local citizens through crowdsourcing. However, the response actors are not always experts, and in many crises, local citizens and the personnel in non-governmental organizations can be highly expert and they can also play a major role in response actions. Therefore, it is important to study how actors with different backgrounds, roles, and levels of expertise in the crisis response field create and share situational information and how they create situational awareness. That would offer new openings for the development of COP systems.

Even though the CACOP concept that was developed is a valuable research result, there are still some open questions that need to be investigated in the future. For example, the concepts of the situational narrative class and the causal relation surface presented in this research are quite simplified. On the causal relation surface presented in this research, the probability of the causal relation depends only on the distances between the instances in the spatial and temporal dimensions. However, it can be assumed that the probability of the causal relation does not always depend only on the distances in the spatial and temporal dimensions, but also on other explanatory factors connected to these distances. The other explanatory factors can be, for example, the potential speed of travel using different means of transport (rivers, roads, etc.) in connection with the distance in the spatial dimension and the time of day or the season in connection with the temporal distance. In the future, it is important to research which explanatory factors define the probability of the causal relation between the instances. Second, this research did not include the implementation of the CACOP concept as a prototype or a user test. It is intended that the prototype and the user tests of it will be included in further research. In the prototype, there will be several optional ways to implement the algorithm which would construct the causal relation surfaces in the situational narrative classes. One possible way is for the users to define the probabilities of the causal relations between the instances that have been included in the situational narratives, after which the system calculates the causal relation surface of the situational narrative class on the basis of the defined probabilities and the spatial and temporal distances between the instances in the situational narratives. Another option is that instead of the user defining the probabilities of the causal relations between the instances in situational narratives, the probabilities would automatically be defined to be 100%, after which the CACOP system would calculate the causal relation surfaces for the situational narrative classes on the basis of the frequency of the 100% causal relations between the instances at all spatial and temporal distances. Calculation methods can be found in the field of GIS. A third recommendation is that the implemented CACOP system should be tested in several types of crises in order to find out the applicability of CACOP in each type of crisis. It can be assumed that the CACOP system would be more appropriate in some types of crises than in other types of crises. A fourth recommendation for future research is associated with the differences between situational information management processes and the SA creation of the experts involved in the crisis response, such as firefighters, and actors who are not experts but are involved in the crisis response, such as local people and the personnel of the non-governmental organizations involved.

The models developed in this research are developed on the basis of literature research and the case studies. It is not assumed that the models are valid in all kinds of crises, in all kinds of cultural contexts, and at all times. The models developed in this research need to be evaluated during the future research and modified when needed, in the same way as any other scientific models and theories.

The IFI matrix has the potential to be a method for creating the situational narrative classes in the semantic database of the CACOP concept manually. As shown in Figure 13, the situational narrative classes develop when the system automatically combines large numbers of sufficiently similar situational narratives. The process of automatically creating the situational narrative classes can require the application of CACOP in a large number of cases before the visualization process of CACOP actually starts identifying the context properly and reducing the problem of information overload. Through collecting the data in the IFI matrix and creating situational narratives manually from that data, the number of cases where CACOP is applied before the visualization process starts functioning properly would be reduced. Technically, the implementation of the semantic database can be performed through a semantic network.

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CROSSOVER

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