From Common Operational Picture to Common Situational Understanding

A Framework for Information Sharing in Multi-Organizational Emergency Management

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Abstract

Complex emergencies such as natural disasters are increasing in frequency and scope, in all regions of the world. These emergencies have devastating impacts on people, property, and the environment. Responding to these events and reducing their impact requires that emergency management organizations (EMOs) collaborate in their operations.

Complex emergencies require extraordinary efforts from EMOs and often should be handled beyond ordinary routines and structures. Such operations involving multiple stakeholders are typically characterized by inadequate information sharing, decision-making problems, limited situational awareness (SA), and lack of common situational understanding. Despite a high volume of research on these challenges, evaluations from complex disasters and large-scale exercises document that there are still several unsolved issues related to information sharing and the development of common situational understanding. Examples here include fulfillment of heterogeneous information needs, employment of different communication tools and processes with limited interoperability, and information overload resulting from a lack of mechanisms for filtering irrelevant information. Multi-organizational emergency management is an established area of research focusing on how to successfully collaborate and share information for developing common situational understanding. However, the level of complexity and situational dependencies between the involved EMOs create challenges for researchers.

An important element for efficient collaboration and information sharing is building and maintaining a common operational picture (COP). Sharing important information is a key element in emergency management involving several EMOs, and both static and dynamic information must be accessible to perform tasks effectively during emergency response. To be proactive and mitigate the emergency impacts requires up-to-date information, both factual information via the COP and the ability to share interpretations and implications through using a communication system for rapid verbal negotiation.

The overall research objective is to investigate how stakeholders perceive and develop SA and COP, and to explore and understand key requirements for

stakeholders to develop a common situational understanding in complex multi-organizational emergency management. The main research question is defined as follows:

How can EMOs establish a COP and further achieve a common situational understanding in complex multi-organizational operations?

To answer the main research question, several sub-research questions were addressed representing various aspects of the phenomenon under study:

• SQ1: How can evaluations after full-scale multi-organizational exercises be carried out for analyzing stakeholders' SA and COP?

• SQ2: What information is important to share, and how, for building a COP in multi-organizational emergency collaboration?

• SQ3: What information and structures are needed for EMOs to create a common situational understanding in response to complex emergency events?

• SQ4: How can different stakeholders utilize IS for communication and data collection to enhance collaboration and achieve common situational understanding?

To answer these research questions, I applied a qualitative research approach involving multiple data collection methods. I conducted an extensive number of interviews with relevant stakeholders from different EMOs, collected and analyzed audio logs from first responder call groups, and also conducted qualitative surveys with first responders related to emergency management exercises. Further, I have participated as an observer in several multi-organizational exercises concerning complex emergency events with different scope. I also participated in the planning and accomplishment of a large-scale tabletop exercise involving a complex wildfire scenario, related to the INSITU project (Sharing incident and threat information for common situational understanding) at the Centre for Integrated Emergency Management (CIEM), University of Agder.

The following theoretical lenses have been applied for analyzing the different aspects of the research question: situational awareness theory, the recognition primed decision (RPD) model, and the normalization process theory (NPT). The SA model and the RPD model helped to understand human decision-making in emergency management. The SA model also emphasizes the concept of Shared Mental Models (SMM), which is an important perspective in this dissertation project as a prerequisite to gaining an understanding of how to achieve efficient multi-organizational collaboration. The NPT is used as a lens to investigate how a new source for data collection (i.e. a live video system) needs to be incorporated in the workflow in a command and control centre.

The empirical findings are presented in six papers published in peer-reviewed international journals and conference proceedings, and a chapter in this dissertation.

Firstly, the results in this dissertation project demonstrate that training and evaluations after multi-organizational exercises can serve as a basis for developing SMM and contribute to an enhanced COP and common situational understanding supporting future emergency response operations. The project contributes with a methodology for post hoc analysis of real-time communication related to establishing a COP after real events and exercises, which offers an important supplementary tool for the evaluation phase. Further, 14 information categories have been identified that together provide an overview of what information is shared at what time in the different phases of a multi-organizational emergency response. The results also suggest how the operational, tactical, and strategic command and control structures (C2S) can establish procedures supporting decision-making by combining the perspectives and conditions for intuitive expertise and the heuristics and biases view.

Secondly, the findings of this research document that a COP represents objective information, and that the COP is a product based on preparation and a structured working methodology that involves shared knowledge across the operational, tactical, and strategic C2S. Since a COP consists of factual information, it does not guarantee that a common situational understanding is achieved, as the involved organizations with different tasks might emphasize the information that mostly concerns themselves. Further, additional and more abstract information

(such as implications and interpretations) must be negotiated through a trading zone for developing a common situational understanding. The study offers lessons on how to connect the operational, tactical, and strategic C2S with up-to-date information by using a national radio network for public safety. This includes what kind of information should be negotiated, how to facilitate the communication paths, and how to solve some of the existing logistical issues by introducing the function of information managers.

Thirdly, the study`s results provide an overview of relevant dynamic and static information that needs to be shared during an extreme weather event and a communication structure for how to share the information. For example, all three C2S are dependent on some of the same information for building a basic understanding of the situation. This constituted the heuristic rule IERO (Incident, Exact position, Resources, Objective description) presented in this dissertation.

Fourthly, this dissertation project demonstrates, by using live video as an example, that effective use of new information sources requires that these are well-incorporated into the EMOs' routines and operative information management systems.

The dissertation project contributes with rich insights and enhances the body of literature concerning the complex processes of multi-organizational emergency management.

A conceptual framework consisting of three fundamental elements of how to get from a COP to a common situational understanding is developed: (1) training for SMM by implementing frequent multi-organizational exercises that build on simple problem-centered scenarios, (2) building a COP by providing the stakeholders with access to available static, dynamic and visual information, and (3) negotiating a common situational understanding by using a secure radio network for sharing semantic and pragmatic information.

Based on practitioner perspectives on the concepts of COP and common situational understanding, a clearer distinction between the two concepts is provided. This conceptual clarification again provides an understanding of the steps involved in developing from one to the other.

The different information sharing practices suggested in this dissertation provide several interesting opportunities for further research. The possible barriers and challenges associated with the implementation of the suggested pre-defined structures for information sharing should be analyzed further. Also, there is a need for more empirical studies to assess the tactical C2S as a trading zone, and the role of information managers at the operational level. Further, there is still a need for more research on the negotiation of different information elements between the C2S and on how to facilitate structures for communication that supplements the factual information provided by the COP.

Sammendrag

Komplekse krisesituasjoner, som for eksempel naturkatastrofer, øker i frekvens og omfang i alle regioner i verden. Slike kriser har ødeleggende konsekvenser både for mennesker, eiendom og miljø. For å håndtere disse hendelsene og redusere de alvorlige konsekvensene, kreves det at beredskapsorganisasjonene samarbeider.

Komplekse krisesituasjoner krever ekstraordinær innsats fra beredskapsorganisasjonene og må ofte håndteres utover vanlige rutiner og strukturer. Slike operasjoner som involverer flere ulike organisasjoner er typisk preget av utilstrekkelig informasjonsdeling, problemer relatert til beslutningstaking, begrenset individuell situasjonsforståelse og mangel på felles situasjonsforståelse. Til tross for et stort forskningsvolum på disse utfordringene, dokumenterer evalueringer fra reelle krisesituasjoner og storskalaøvelser at det fortsatt er flere uløste problemstillinger knyttet til informasjonsdeling og utvikling av felles situasjonsforståelse. Eksempler her inkluderer oppfyllelse av heterogene informasjonsbehov, bruk av ulike kommunikasjonsverktøy og prosesser med begrenset interoperabilitet, og informasjonsoverbelastning som følge av mangel på mekanismer for filtrering av irrelevant informasjon. Krisehåndtering som krever at flere ulike organisasjoner må involveres er et etablert forskningsområde som setter søkelys på hvordan man kan samarbeide og dele informasjon for å utvikle felles situasjonsforståelse. Kompleksitetsnivået og ulikhetene mellom de involverte organisasjonene skaper imidlertid utfordringer for denne forskningen.

Et viktig element for effektivt samarbeid og informasjonsdeling er å bygge og vedlikeholde et felles operasjonsbilde. Deling av viktig informasjon er et sentralt element i krisehåndtering som involverer flere organisasjoner, og både statisk og dynamisk informasjon må være tilgjengelig for å utføre oppgaver effektivt under håndteringen. For å være proaktiv og dempe de negative konsekvensene kreves det oppdatert informasjon, både faktainformasjon via det felles operasjonsbildet og muligheten for å kunne dele tolkninger og implikasjoner gjennom bruk av et kommunikasjonssystem for verbale forhandlinger.

Det overordnede temaet for denne forskningen er å undersøke hvordan beredskapsaktørene i krisehåndtering forstår og etablerer situasjonsforståelse og felles operasjonsbilde, og å utforske og forstå nøkkelbehov til aktørene for å utvikle en felles situasjonsforståelse i krisehåndtering der flere ulike organisasjoner er involvert. Forskningsspørsmålet er definert som følger:

Hvordan kan krisehåndteringsorganisasjoner etablere ef felles operasjonsbilde og videre oppnå en felles situasjonsforståelse i håndteringen av komplekse krisesituasjoner?

For å svare på dette spørsmålet, ble flere delspørsmål (SQ) som representerte ulike aspekter ved fenomenet utformet:

• SQ1: Hvordan kan evalueringer etter fullskala samvirkeøvelser gjennomføres for å analysere de involverte beredskapsaktørenes situasjonsforståelse og felles operasjonsbilde?

• SQ2: Hvilken informasjon er viktig å dele, og hvordan, for å bygge et felles operasjonsbilde i krisehåndtering der flere ulike organisasjoner er involvert?

• SQ3: Hvilken informasjon og strukturer trengs for at beredskapsorganisasjonene skal skape en felles situasjonsforståelse i krisehåndteringen?

• SQ4: Hvordan kan ulike beredskapsaktører bruke informasjonssystemer for kommunikasjon og datainnsamling for å styrke samarbeidet og oppnå felles situasjonsforståelse?

For å svare på disse forskningsspørsmålene brukte jeg en kvalitativ forskningstilnærming som involverer flere datainnsamlingsmetoder. Jeg gjennomførte et omfattende antall intervjuer med relevante aktører fra beredskapsorganisasjoner, samlet inn og analyserte lydlogger fra felles talegrupper blant nødetatene, og distribuerte spørreskjemaer blant nødetater knyttet til beredskapsøvelser. Videre har jeg deltatt som observatør i flere samvirkeøvelser av ulikt omfang. Jeg deltok også i planleggingen og gjennomføringen av en storstilt tabletop øvelse som involverte et komplekst

skogbrannscenario, relatert til INSITU-prosjektet (Sharing incident and threat information for common situational understanding) ved Center for Integrated Emergency Management (CIEM), Universitetet i Agder.

Følgende teoretiske perspektiver er brukt for å analysere de ulike aspektene ved forskningsspørsmålet: Situational Awareness (SA) teorien, Recognition Primed Decision (RPD) modellen, og Normalization Process teorien (NPT). SA-teorien og RPD-modellen bidro til å forstå menneskelig beslutningstaking i krisehåndteringssituasjoner. SA-teorien vektlegger også begrepet *delte mentale modeller*, som er et viktig perspektiv i dette doktorgradsprosjektet som en forutsetning for å få forståelse for hvordan man kan oppnå effektivt samvirke. NPT benyttes for å undersøke hvordan en ny kilde for datainnsamling (dvs. et videosystem) må innarbeides i arbeidsflyten i en nødsentral.

De empiriske funnene presenteres i seks artikler publisert i fagfellevurderte internasjonale tidsskrifter og konferanser, og som et kapittel i denne avhandlingen.

For det første viser resultatene i dette doktorgradsprosjektet at både hyppig trening, og evalueringer av samvirkeøvelser kan tjene som grunnlag for å utvikle delte mentale modeller og bidra til et forbedret felles operasjonsbilde og felles situasjonsforståelse som støtter fremtidig krisehåndtering. Prosjektet bidrar med en metodikk for post hoc analyse av sanntidskommunikasjon knyttet til etablering av felles operasjonsbilde etter reelle hendelser og øvelser som et viktig supplerende verktøy for evalueringsfasen. Det er videre identifisert 14 informasjonskategorier som til sammen gir en oversikt over hvilken informasjon som deles til hvilket tidspunkt i de ulike fasene i en krisehåndteringssituasjon. Resultatene antyder også hvordan de operative, taktiske og strategiske kommando- og kontrollstrukturene (C2S) kan etablere prosedyrer som støtter beslutningstaking ved å kombinere perspektivene og betingelsene for intuitiv ekspertise.

For det andre dokumenterer funnene i denne forskningen at et felles operasjonsbilde representerer objektiv informasjon, og at det felles operasjonsbildet er et produkt basert på forberedelse og en strukturert arbeidsmetodikk som involverer delt kunnskap på tvers av det operasjonelle,

taktiske og strategiske C2S. Siden et felles operasjonsbilde består av faktainformasjon, garanterer den ikke at en felles situasjonsforståelse oppnås, ettersom de involverte organisasjonene med sine ulike oppgaver og perspektiver kan legge vekt på informasjonen som hovedsakelig angår dem selv. Videre må ytterligere og mer abstrakt informasjon (som implikasjoner og tolkninger) forhandles gjennom en «trading zone» for å utvikle en felles situasjonsforståelse. Studien tilbyr forslag om hvordan man kobler den operative, taktiske og strategiske C2S med oppdatert informasjon ved å bruke Nødnett for verbal kommunikasjon. Dette inkluderer hva slags informasjon som skal deles, hvordan man legger til rette for kommunikasjonsveiene, og hvordan man løser noen av de eksisterende logistikkproblemene ved å introdusere funksjonen *Information Manager*.

For det tredje gir studiens resultater en oversikt over relevant dynamisk og statisk informasjon som må deles under en ekstremværhendelse og en kommunikasjonsstruktur for hvordan man kan dele informasjonen. For eksempel er alle tre C2S avhengige av noe av den samme informasjonen for å bygge en grunnleggende forståelse av situasjonen. Dette utgjorde tommelfingerregelen *IERO* (Incident, Exact position, Resources, Objective description) presentert i denne avhandlingen.

For det fjerde demonstrerer dette avhandlingsprosjektet, ved å bruke video som et eksempel, at effektiv bruk av nye informasjonskilder krever at disse er godt integrert i organisasjonenes rutiner og operative systemer.

Studien bidrar med rik innsikt og forsterker litteraturen om de komplekse prosessene ved krisehåndtering som involverer flere ulike beredskapsorganisasjoner.

Et rammeverk som består av tre grunnleggende elementer for hvordan man kommer fra et felles operasjonsbilde til en felles situasjonsforståelse er utviklet: (1) opplæring for å utvikle delte mentale modeller ved å gjennomføre hyppige samvirkeøvelser som bygger på enkle problemsentrerte scenarier, (2) bygge et felles operasjonsbilde ved å gi aktørene tilgang til tilgjengelig statisk, dynamisk og visuell informasjon, og (3) forhandle en felles situasjonsforståelse ved å bruke et sikkert radionettverk for å kunne dele semantisk og pragmatisk informasjon.

Basert på beredskapsaktørenes perspektiver på begrepene felles operasjonsbilde og felles situasjonsforståelse, gis det et klarere skille mellom de to begrepene. Denne konseptuelle avklaringen gir igjen en forståelse av trinnene som er involvert i utviklingen fra det ene til det andre.

De ulike praksisene for informasjonsdeling foreslått i denne avhandlingen gir flere interessante muligheter for videre forskning. De mulige barrierene og utfordringene knyttet til implementeringen av de foreslåtte forhåndsdefinerte strukturene for informasjonsdeling bør undersøkes videre. Det er også behov for mer empiriske studier for å vurdere taktisk C2S som en sone for informasjonsdeling, og rollen til Information Managers på operasjonelt nivå. Videre er det fortsatt behov for mer forskning på forhandling av ulike informasjonselementer mellom C2S og om hvordan man kan legge til rette for strukturer for kommunikasjon som supplerer den faktiske informasjonen gitt av det felles operasjonsbilde.

List of Abbreviations

4C	Cognition, Communication, Coordination, and Control
COP	Common Operational Picture
C2S	Command and Control Structure
DM	Decision-making
DSA	Distributed Situational Awareness
EM	Emergency Management
EMO	Emergency Management Organizations
ER	Emergency Response
MM	Mental Model
SMM	Shared Mental Model
SA	Situational Awareness
IS	Information Systems
GIS	Geographical Information Systems
CIEM	Centre for Integrated Emergency Management
BAPS	Fire, ambulance, and police collaboration call group
NPT	Normalization Process Theory
NPSN	Norwegian Public Safety (radio) Network
DSB	Norwegian Directorate for Civil Protection
IERO	Incident, Exact position, Resources, Objective description
IC	Incident Commander
NDM	Naturalistic Decision Making
HB	Heuristics and Biases

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1 Introduction

1.1 Background

Emergency management organizations (EMOs) are currently facing huge challenges regarding how to collaborate and coordinate to cope with the devastating impacts of complex disasters – that is, disasters requiring a response that goes beyond the mandate or capacity of any single agency (Greenwood et al., 2017). Emergency management (EM) of complex events is increasing in frequency and scope, resulting from natural and man-made hazards. Climate change is currently the greatest challenge, and the evidence of human impact is stronger than ever (Jones, 2019). Norway`s emergency preparedness and response have been challenged in several major incidents ranging from extreme weather to terror attacks. Examples are the winter storms Dagmar (2011), Tor (2016), and Urd (2016), and the terror attack on 22 July (2011) (Gjørv, 2012; Taleb, 2007). All types of government stakeholders recognize an enhanced need to collaborate to address such complex events (McEntire, 2007), which by their nature may affect all sectors of the population (Buckle, 1999).

Complex events require extraordinary efforts from the authorities and cannot be handled through ordinary routines and structures. These emergency operations involve multiple stakeholders, which often triggers inadequate information sharing (Waterman et al., 2021) and decision-making problems (Wang et al., 2020). There are developed principles for guiding the collection, checking, sharing, and use of information processes for supporting collaboration and decision-making; however, research has proven this is extremely challenging in complex disaster settings (Van de Walle and Comes, 2015). There is a need to focus on identifying concrete elements that facilitate information sharing in multi-organizational EM (Waring, 2018).

Complex events require effective EM because of the consequences and scope for human survival, material damage, and critical infrastructure in both the acute and later phases. The EM phases (mitigation, preparedness, response, and recovery) must be planned, coordinated, and executed for successful EM. In this dissertation, the preparedness and response phases are considered for investigating, explaining, and suggesting solutions for the problem of

information sharing and building common situational understanding in complex events. The preparedness phase includes the knowledge and capacities that stakeholders in various EMOs are developing to anticipate, respond to, and recover from emergency events (United Nations, 2009) – for example, planning, training, and educational activities. The response phase is the immediate reaction to emergency events and includes, for example, implementing disaster response plans and search and rescue missions.

Situational Awareness (SA) is important for the actors from different agencies for supporting decision-making and responding to different situations. SA concerns the stakeholders` perception and understanding of the world employing future projections of its current situation (Endsley, 1995). The development in technological support has enabled humans to act more effectively in decision-making when operating in dynamic systems (Endsley, 1995). Several studies in different domains have shown that one of the key factors for human mistakes during critical environments is a lack of SA. For instance, in an air transport system, as much as 88% of human errors are due to SA problems (Endsley, 2018). Managing new and unknown emergencies is a challenge because humans tend to find explanations that give a sense of control. Those explanations turn unknown situations into known, and therefore, they become "true." However, they are in many cases serious misjudgments (Weick and Sutcliffe, 2015). To avoid misjudgments and hasty conclusions, it is important to consider that stress affects decision-making (Steigenberger, 2016). Also, the information gap and overload further complicate decision-making and create simplified mental models (Van den Homberg et al., 2018), which again can lead to poorer decisions. The capabilities and complexity of the information systems for information gathering and presentation are also significant factors that affect SA (Endsley, 2015).

Response to complex disasters requires coordination between EMOs across the command and control structures (C2S), such as first responders, non-governmental organizations (NGOs) and municipalities, which are organizations that seldom interact in their day-to-day duties. To achieve effective EM, the involved EMOs must act rapidly in a coordinated manner (Osatuyi and Mendonca, 2010). The coordination between several organizations involves heterogeneous information needs, processes/structures, goals, resources,

technology, and other features within the organizations (Bharosa et al., 2010). This poses challenges in different organizations, and typical problems are a mismatch between goals, procedures that do not correspond, information overload, ignorance/inability to determine what information needs to be shared, and time pressure, among other things. EMOs have difficulty in understanding each other's concepts (Carlström et al., 2019), such as hierarchy levels, action logics, and agendas (Berlin and Carlström, 2008). All in all, coordination during emergency response is a challenging task, and the complexity of an emergency increases with the number of EMOs involved.

The practices of crisis preparedness, response, and recovery have over the past two decades become increasingly dependent on information and communication technology (ICT) to perform the tasks (Soden and Palen, 2018). There is also much research focusing on how to develop and use different information systems (IS) for assisting the stakeholders in responding to emergencies (e.g., Gjøsæter et al., 2021; Rossel et al., 2016; Valecha, 2019). The stakeholders in the different EMOs need to have available systems for information analysis and decision support, both specific for each organization and for supporting collaboration and information sharing (Van De Walle et al., 2014). For example, the IS must support the coordination of efforts and collaboration of several involved organizations during complex emergencies. The literature frequently points to a common operational picture (COP) as an important element for efficient collaboration. A COP is commonly viewed as a "centralized information display system" (Hwang and Yoon, 2020, p. 2), as it displays relevant operational information, such as positions, infrastructure, and different resources (Karagiannis and Synolakis, 2016). A COP can also function as a checklist of the characteristics in a certain situation (Wolbers and Boersma, 2013), and it forms the basis for EMOs to meet the challenges in complex emergency operations (Borglund, 2017). The concept of COP is a core focus in IS-related conferences such as the International Conference on Information Systems for Crisis Response and Management (ISCRAM), the IFIP WG5.15 conference on IT in Disaster Risk Reduction (ITDRR) and dedicated tracks in the Hawaii International Conference on System Sciences (HICCS). There is, however, still no univocal definition of the COP term (Pilemalm et al., 2021).

The literature largely refers to the COP when it concerns collaboration and information sharing. Sharing important information is a key element in EM involving several EMOs, and both static information (such as buildings, critical infrastructure, and roads) and dynamic information (such as location of victims, first responder resources, and roadblocks) must be accessible to perform tasks effectively during an emergency response (Treurniet and Wolbers, 2021). The COP can also include different common procedures based on SA and decision-making theories, as well as the ability to capture interrelationships between the operational information. The information included in a COP can be described as factual information that might be interpreted differently among the involved actors. Successful information sharing provides an increase of the common ground, which further leads to improvement in team performance (McNeese et al., 2006). Using different IS for COP development can create the needed workspace for collaboration. Examples of such IS are handheld airwave radio devices, internet-based technologies, and geographical information systems (GIS).

To be proactive and mitigate emergency impacts, there is a need for up-to-date information, both factual information via a COP, and the ability to share interpretations (i.e., semantic information level) and implications (i.e., pragmatic information level) by using an IS for rapid negotiation (Van de Walle et al., 2016). A COP with factual information does not guarantee a common situational understanding, as the involved organizations with different tasks might emphasize the data that mostly concern themselves (Bindl, 2005). A common situational understanding demands reconciling a range of perspectives, options, and changes that often challenge the stakeholders involved in EM (Bunker et al., 2015). In the aftermath of several big disasters, such as the Gjerdrum Landslide in Norway in 2020 (Joint Rescue Coordination Centre, 2021), the 9/11 terrorist attacks in the United States in 2001 (Dearstyne, 2007), the 22 July 2011 Norway massacre (Gjørv, 2012), and Hurricane Katrina in 2005 (Boin, Brown, and Richardson, 2019), a lack of relevant, cross-organizational information sharing resulted in an insufficient common situational understanding. One of the reasons for this is that most information systems used for emergency management only facilitate information sharing and not the collaboration process (Valecha, 2019). In addition, many EMOs do not use the same map interface and only operate with tools supporting verbal communication in the collaboration process.

However, verbal communication tools may be the best way to handle information at the semantic (i.e., interpretations) and pragmatic (i.e., implications) information levels.

The future will involve more complex disasters and incidents, and EMOs must prepare for extraordinary efforts in collaboration. There is a need to focus on challenges such as inoperable procedures for decision-making, lack of efficient communication structures, and different tools and use of IS. The information sharing and decision-making problems are caused by, and cause, insufficient levels of important concepts such as SA, COP, and common situational understanding among the involved stakeholders.

While several studies have contributed to developing a conceptual understanding of COP (e.g. Hwang and Yoon, 2020; Luokkala et al., 2017) there is still limited research on how stakeholders from the different EMOs interact and communicate in the process of establishing a COP and further develop common situational understanding. This dissertation project investigates the stakeholders' perspectives and practices related to the concepts of COP and common situational understanding and establishes a framework that describes how elements such as collaboration exercises, COP, and communication structures are intertwined for developing a common situational understanding.

Given the challenges involved in the collaboration process between several EMOs, there is a need to enhance the capability of EMOs to handle multi-organizational operations caused by complex disasters. How to develop a common situational understanding between the involved EMOs is a process requiring insight and knowledge sharing between the actors involved both before and during a crisis, where both common and individual information needs, terms, strategies, and procedures must be structured and implemented as a process using IS support in the different organizations. When this is implemented, the information sharing process will be more efficient and accurate and will ensure that every professional stakeholder, despite their different experiences, is guided to the most important information and thus can make better decisions.

1.2 Research setting

The research setting for this dissertation project is Norwegian EMOs, with a special focus on the organizations involved in the management of complex crisis response scenarios. The response must be handled by several EMOs across the different levels of the C2S, such as the first responder agencies (i.e., fire, health, and police services), municipalities, NGOs (in this case, the Red Cross), the County Governor (supervisory authorities), and critical infrastructure organizations (physical and cyber-based systems, in this case, energy, transport, and communications). The Norwegian EM model is based on decentralized responsibility, and this is reflected in the following four basic principles guiding societal safety, contingency planning, and crisis management in Norway (NOU, 2001, p. 31; Rimstad et al., 2014; Ministry of Justice and Public Security, 2012):

1. The *principle of responsibility* concerns that the authority responsible for a function on a day-to-day basis is also responsible for implementing necessary action in times of crisis.

2. The *principle of proximity* states that crises are to be managed at the lowest appropriate level in the organization.

3. The *principle of similarity* is about how the appropriate everyday procedures, resources, and organizational structures must be used in both normal conditions and crises.

4. The *principle of cooperation* makes it mandatory for both public and private stakeholders to assist in a collective EM with whatever relevant resources they might have.

The Norwegian public administration has three levels, national, regional, and local, whereas the political system is characterized by strong sector ministries. These ministries are responsible for all policies and activities in their respective domains combined with decentralized local governance (Fosse et al., 2022). The national and regional levels have reduced direct control over the municipalities (The Local Government Act, 2018).

First responder organizations are the main stakeholders when handling an acute crisis (Figure 1), both for agency-specific and multi-agency operations. Each of these first responder agencies has its command and control center (CCC). The CCCs' main tasks are to control the operative unit's fleet consisting of different resources, e.g., ground, air, and water vehicles. Further, they act according to certain protocols and the dispatchers` professional experience. The CCCs` responsibility does not include leading the operation itself or managing efforts at the scene of the incident. This is the responsibility of the incident leaders on the emergency site. However, the CCCs support operative field management and participate in decision-making (Norri-Sederholm et al., 2017). They must follow an operation until measures are terminated, e.g., following an ambulance transport in their GIS until arriving at the hospital. The CCCs have different information sharing structures, working processes, and technological tools that are not well integrated among the organizations. They also have different emergency phone numbers (110, 112, and 113); however, the different systems possess a function to easily route the emergency calls between the centers. They have a predefined information exchange structure – for example, what kind of emergency it is (incident category) and what kind of resources are required for handling it.

When an emergency occurs, an organizational structure for facilitating multi-agency emergency response is established at the incident scene (Rimstad, 2014). Each of the involved EMOs has an Incident Commander (IC) at the emergency site; however, the police is overall responsible for all emerency response activities within their geographical districts.

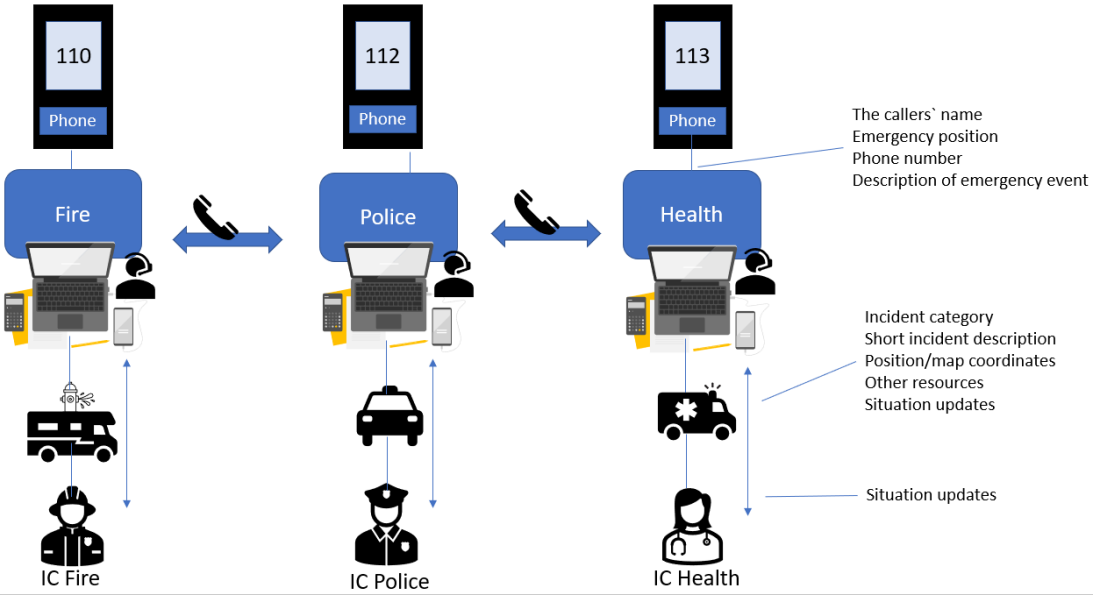

Figure 1: First responders' communication process and technology support

The CCCs in Norway are currently going through a significant renewal process of both incident management tools and tools for tactical work in the field. The new IS are expected to provide better technical support, increased system resilience, and opportunities for collaboration which underpin the first responders' dependency on IS for performing EM. Such IS should support the stakeholders to achieve common situational understanding by deploying a COP (Giaoutzi and Scholten, 2017). However, these systems are not designed with exactly the same purpose in mind, thus there is still no single system that is commonly used by all involved stakeholders across the EMOs. An important notion is that the IS itself cannot solve the interoperability problem. The core of the problem lies with how the stakeholders in the different EMOs choose to work together rather than how they choose to communicate (Kapucu et al., 2010).

On the higher level of coordination, the Ministry of Justice and Public Security with its subordinate agency, the Directorate for Civil Protection (DSB), has superior responsibility for emergency management. The other ministries have, together with the health authorities and the municipalities, independent responsibilities for emergency management in their areas of jurisdiction. The county governor has an important role as the state`s regional representative, and together with the affected chief of police, they establish contact and evaluate the situation. The county governor contacts the Directorate for Civil Protection

(DSB) and/or other possibly relevant directorates and further establishes mutual information exchange with regional actors, such as owners of critical infrastructure and affected municipalities. Further, the county governor establishes the County Emergency Preparedness Council. This council provides mutual situation updates to create SA, map further needs for resources, and allocate responsibilities among the participating organizations. The county governor continuously informs central authorities. In EM of complex events, the municipalities play a central role, as they are tasked with safety at the local level and therefore are an important part of the EM system. The municipality collaborates with internal and external emergency organizations in large events (Regulation on Municipal Emergency Duty, 2011).

Figure 2 presents an example of the stakeholders involved in a large-scale multi-organizational emergency scenario and the information flow among the involved organizations.

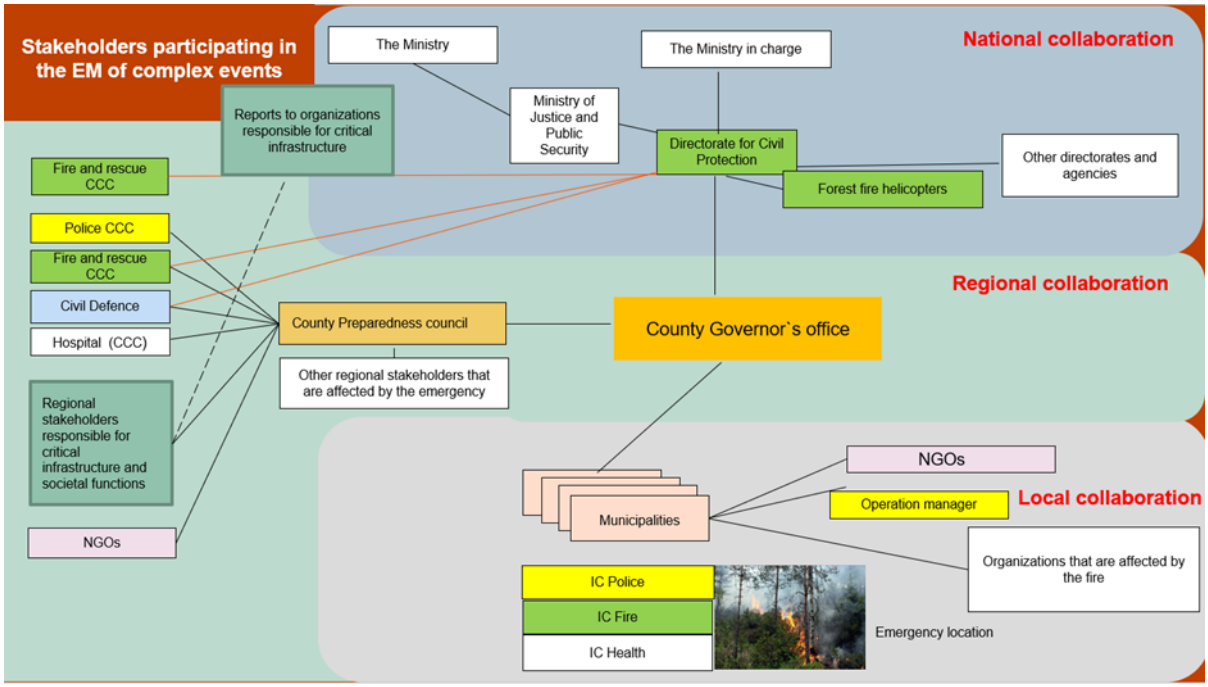

Figure 2: An overview of stakeholders involved in a complex emergency event (Source: the County Governor of Agder)

Several information systems for communication and information sharing between the EMOs in Norway related to various activities and phases in response operations are in use; however, there is limited integration between the systems, which results in a general lack of tools for sharing information between the

organizations (Munkvold et al., 2019). This is a major challenge because the lack of a COP is one of the major factors for ineffective multi-organizational EM (Giaoutzi and Scholten, 2017). See Appendix F for a summary of the current practice with IS-supported communication and information sharing between the EMOs in Norway.

The motivation for undertaking this dissertation project is partly based on my experience as a former emergency dispatcher in a health command and control center (CCC). I have thus firsthand experience with the challenges caused by insufficient SA and common situational understanding. My background has also provided me with a network of contacts for this dissertation project.

1.3 Research questions

Despite a high volume of studies on EM, evaluations from complex disasters and large-scale exercises have documented several issues related to information sharing, such as heterogeneous information needs, different communication tools and processes, and information overload due to a lack of filtering of irrelevant information (e.g., Bunker et al., 2015; Steigenberger, 2016; Wolbers and Boersma, 2013), and the development of a common situational understanding related to multi-organizational emergency response (Munkvold et al., 2019). Further, poor collaboration during multi-organizational EM has negative consequences on decision-making and actions (e.g., Junglas and Ives, 2007; Helsloot, 2005; Dawes et al., 2004).

The overall research objective of this dissertation project is to explore and understand the key requirements for stakeholders to develop a common situational understanding in complex multi-organizational EM. The main research question (RQ) is defined as follows:

How can EMOs establish a COP and further achieve a common situational understanding in complex multi-organizational operations?

To answer the main RQ, I began by reviewing the EMOs` collaboration practices and what kind of IS they use for collecting and sharing information. The review

identified several research objectives and provided suggestions for how to structure the dissertation project. First, there is a need for understanding how the EMOs can enhance their collaboration practices which can be done through exercises and evaluations. Thus, a first subquestion (SQ1) was developed to provide knowledge on how to utilize collaboration exercises for stakeholders to build a COP in unpredictable and complex working environments:

SQ1: *How can evaluations after full-scale multi-organizational exercises be carried out for analyzing stakeholders' SA and COP?*

Secondly, both the initial review and the results from the first stage of the research documented that there is a need for the stakeholders to learn about their mutual information requirements to support the information sharing processes for developing a COP. Therefore, SQ2 was defined as follows:

SQ2: *What information is important to share, and how, for building a COP in multi-organizational emergency collaboration?*

The need for insights into the complexity of common situational understanding and the COP term emerged from the results and analysis of SQ1 and SQ2. For example, the initial interviews identified that the respondents had different perspectives on the terms. The literature also includes several debates surrounding the basic meaning of COP, and likewise, the broader concept of common situational understanding suffers from similar conceptual diversity. The mutual information requirements identified earlier suggest that there is an important difference between factual information and stakeholders` interpretations and implications, and that this information can be shared using different IS. Since the COP mainly conveys factual information, there was a need for investigating what information and main structures are needed for creating common situational understanding:

SQ3: *What information and structures are needed for EMOs to create a common situational understanding in response to complex emergency events?*

The result from the studies related to the previous SQs documented that the stakeholders in this dissertation project characterized COP as a representation of

objective information while common situational understanding is achieved through a common interpretation of the information. The use of different IS as the infrastructure for building a COP and further developing common situational understanding also required investigation for answering the main RQ. There are several different IS in use during the EM processes among the EMOs, and the related practices were shown to be fragmented. SQ4 was thus framed as follows:

SQ4: *How can different stakeholders utilize IS for communication and data collection to enhance collaboration and achieve a common situational understanding?*

To answer these SQs, qualitative interviews of relevant stakeholders were conducted, audio logs were analyzed, and relevant literature was reviewed. Further, I observed three multi-organizational exercises concerning complex emergency events with different scopes: a multi-terror incident, a forest fire scenario, and a missing person/drowning incident. Lastly, I participated in the planning and accomplishment of a tabletop exercise on a complex wildfire scenario related to the INSITU (Sharing Incident and Threat Information for Common Situational Understanding) project at the Centre for Integrated Emergency Management, University of Agder (Munkvold et al., 2019).

1.4 Overview of core theoretical perspectives

To address the research objective, several theoretical frameworks were employed, as this contributes to a higher understanding of complex phenomena occurring in the social world (Mueller and Urbach, 2013). The core theoretical perspectives used throughout the dissertation project are the SA model (Endsley, 1995), the recognition-primed decision (RPD) model (Klein and Crandall, 1996), and the normalization process theory (NPT) (May and Finch, 2009). These models/theories were chosen because they have the potential to help researchers to understand how humans interact with their environments. The model of SA is chosen because it covers the understanding of information processing in the current status and includes the projection of future status and how it affects decision-making. The RPD covers how experts make decisions during time pressure, and the NPT helps to identify the usefulness of IS in such highly

complex environments. Thus, these theoretical perspectives provide a foundation for understanding the effective use of IS in the response phase of EM.

The three theoretical lenses can be summarized as follows:

The SA model defines three levels of awareness (perception, comprehension, and projection) and is described as "an ongoing dynamic process of gathering and interpreting information to update the situation model and using that situation model to search for information until decisions can be made" (Endsley, 2015, p. 6). In this dissertation project, the model provides a structure for systematizing and explaining SA levels among involved actors and for the categories and elements of COP and common situational understanding. The SA model emphasizes the concept of *shared mental models (SMM),* which is an important perspective in this dissertation project as a prerequisite to gain an understanding of how to achieve efficient multi-agency collaboration.

The SA model is complemented with selected decision-making theories. There is a strong connection between SA and decision-making processes, where a higher SA level results in better decisions (Stanners and French, 2005). The stakeholders' SA cues, which are perceived and comprehended by experts, lead to actions that have gone through both mental and organizational processes. The SA model explains various factors that affect the decision-making process – for example, if there is a lack of expertise, there is an absence of naturalistic decision-making (NDM) heuristics, such as intuition and mental simulation (ibid).

The RPD model (Klein and Crandall, 1996) offers an important contribution to the cognitive aspects of this dissertation project. In time-critical operations, stakeholders must act quickly upon the available information, and the RPD model offers an analytical process to reach a decision. This model explains NDM processes made by experts in their natural environments – where the focus is more "front loaded," as the stakeholders refresh their SA through feedback rather than through developing multiple options (Zsambok and Klein, 2014). Since multi-organizational EM must be based on procedures and experience from several actors, the theory for the cognitive process can and should be the basis for the development of procedures. However, as documented from the results of this

Ph.D. project, different procedures require a different set of decision-making theories. Therefore, *Kahneman's (2011) dual-system theory* is also discussed in this dissertation project as more or less the opposite to the RPD model, emphasizing the biases of the human unconscious mind. This traditional decision theory emphasizes the understanding of the "back end" of the decision – namely, choosing among several options (Zsambok and Klein, 2014). These theories lay the groundwork for the discussion on procedures and structures implemented in the COP. *Sensemaking* (Weick, 1995) is the "interplay between action and interpretation," further "bringing meaning into existence." Since stakeholders collect information that fits their professional standpoint and therefore develop different perspectives of situations, the sensemaking process is an important component when focusing on information sharing to achieve a common situational understanding (Wolbers and Boersma, 2013). Sensemaking contributes to SA model by asking *why were [these] actions taken?* and thus explains the development between the stakeholders` experiences in a situation and future practice.

NPT (May and Finch, 2009) was chosen to analyze how new information sources are incorporated into complex work environments, such as in CCCs. In this dissertation project, the theory is used as a lens to investigate how a new data collection system intervenes in existing workflows and to determine whether there are any workflow issues when implementing novel systems for information collection in C2S.

1.5 Results

The results of this dissertation project are mainly presented in the following six articles (table 1), which have been published in international journals and international conference proceedings. The full texts of the articles are included in Appendix G.

Table 1: Scientific publications

#	Article
1	Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *Using audio-logs for analyzing the development of a common operational picture in multi-agency emergency response*. In Proceedings of the 53rd Hawaii International Conference on System Sciences, Maui, HI (USA).
2	Steen-Tveit, K. (2020). *Identifying information requirements for improving the common operational picture in multi-agency operations*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management, Virginia Tech, Blacksburg, Virginia (USA).
3	Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management, Virginia Tech, Blacksburg, Virginia (USA).
4	Steen-Tveit, K., & Munkvold, B. E. (2021). From common operational picture to common situational understanding: An analysis based on practitioner perspectives. *Safety Science, 142,* Article 105381.
5	Steen-Tveit, K. (2022). *Using a public safety radio network for information negotiation between the three-tiered command and control structure.* In Proceedings of the 55th Hawaii International Conference on System Sciences (Virtual Conference).
6	Steen-Tveit, K., Munkvold, B. E., & Radianti, J. (2021). Using live video for communication between lay bystanders and emergency dispatchers in command and control centers. *International Journal of Emergency Management,* Vol. 17, No. 2, pp. 154–176.

The dissertation project's results together constitute the basis for the proposed framework presented in Chapter 7, defining a process for developing a common situational understanding in multi-organizational EM. The dissertation project offers rich insights and enhances the body of literature concerning the complex

processes of multi-organizational EM and contributes important steps when developing new procedures and tools in practice.

1.6 Dissertation structure

The structure of the remaining chapters of the dissertation is as follows:

- **Chapter 2** provides a brief overview of the definitions and concepts included in the dissertation project.
- **Chapter 3** gives an overview of related research in emergency management and use of information systems, including emergency management phases and response, collaboration in EM, COP, and common situational understanding.
- **Chapter 4** introduces the theoretical perspectives chosen as a basis for the research –SA model, decision-making theories, and Normalization Process Theory.
- **Chapter 5** describes the research approach used to address the four SQs. Further, the chapter clarifies the philosophical foundation and describes the research strategy (interpretive case studies), methods (interviews, observations, document analysis), data analysis, and validity issues.
- **Chapter 6** summarizes the findings from the six dissertation articles.
- **Chapter 7** discusses the results and presents the proposed framework that constitutes the main contribution of this study.
- **Chapter 8** concludes the dissertation, by presenting a summary of the results and providing theoretical and practical implications and suggestions for further research and the limitations of the research design.

2 Definition of core concepts

This chapter aims to clarify relevant terms and introduce an overview of important definitions and concepts in the emergency management domain, including the command and control structures, collaboration in EM operations, the use of IS and technologies for EM, COP, training, and evaluations of exercises and real events.

2.1 Emergency management (EM)

Different crises have always been a part of society, and crises described hundreds of years ago still occur regularly. The public expects the authorities to avert or minimize the consequences. The quality of EM can, in many cases, mean the difference between life and death. EM is based on the concept of continuous improvement, which makes it an evolving, dynamic field. Each disaster that occurs provides new challenges and new solutions (Canton, 2019).

The Federal Emergency Management Agency (FEMA) defines EM as "the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters." From a sociologist's view, EM is defined as

> the process by which the uncertainties that exist in potentially hazardous situations can be minimized and public safety maximized. The goal is to limit the costs of emergencies or disasters through the implementation of a series of strategies and tactics reflecting the full life cycle of a disaster, i.e., preparedness, response, recovery, and mitigation. (Drabek and Evans, 2007, p. 4).

No major emergency is ever tackled by a single organization. Rather, it requires a network of several EMOs that cut across disciplinary, jurisdictional, and public-private sector boundaries (Kapucu, 2010).

Bardach (1998) defines collaboration between public sector organizations as "any joint activity by two or more agencies that are intended to increase public value by their working together rather than separately" (p. 8). When several stakeholders from different organizations must collaborate for a successful outcome, they must have the same sense of purpose and a clearly defined goal.

2.2 Command and control structures (C2S)

The term three-tiered command structure (Bharosa et al., 2010; Waring et al., 2020) refers to the operational, tactical, and strategic C2S as three distinct levels (figure 3). The operational C2S is defined as the first responders working on the scene, the tactical C2S as the local incident management team supporting the actors on the scene, and the strategic C2S as the stakeholders working at the regional, state, or national level (Owen et al., 2016; Waring et al., 2018). (See thesis Article #6, figure 1 for a more detailed illustration.) The organizations in the different C2S have the following tasks:

Strategic C2S: Manage and coordinate the response work to safeguard overall interests and concentrate on the EMOs' environment.

Tactical C2S: Manage, coordinate, and support the operational level through competence, capacity, and communication. Further, concentrate on the first responders and evacuated victims.

Operational C2S: Manage and coordinate on, or close to, the incident scene to prevent or reduce harm to people, property, and the environment.

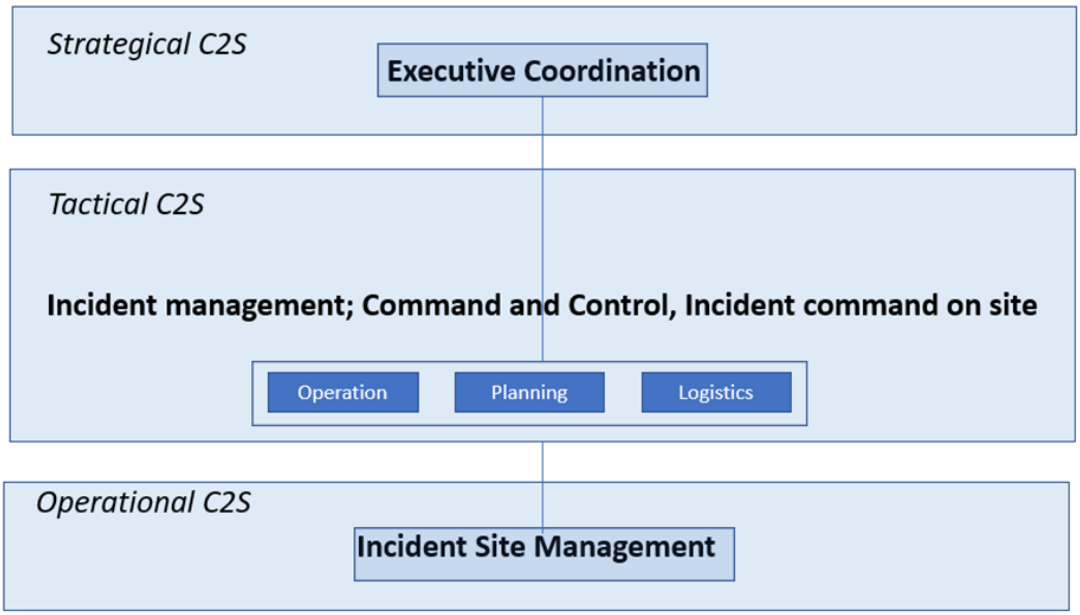

Figure 3: Organization of management levels in the three-tiered command and control structure (adapted from Lunde, 2014)

There are different terms used for the different C2S, especially within the operational and tactical C2S, and the terms tend to get mixed between several organizations and sectors. This constitutes a challenge for clear communication

and understanding between the different EMOs, and the introduction of standardized terms for the different C2S would be beneficial (Lunde, 2014). This dissertation project draws on the three-tiered C2S, as it illustrates a general description of the different mandates within the involved organizations.

For structuring the communication process and enabling fast decision-making, the EMOs employ a centralized C2S. The command process aims to communicate intentions and the control process consists of a high amount of communication exchanges and coordination activities, with efficiency as a goal. Command and control functions are performed through "an arrangement of personnel, equipment, communications, facilities, and procedures which are employed by a commander in planning, direction coordination and controlling forces and operations in the accomplishment of the mission" (Builder, 1999, p. 11). The involved organizations' tasks and perspectives are different due to where they are located in the C2S (figure 3). However, such a command and control structure is difficult to maintain during the response phase of complex events where a large number of EMOs are involved. An important challenge is that information sharing becomes increasingly complex due to heterogeneous information needs, different communication tools and processes, and information overload due to a lack of filtering of irrelevant information (e.g., Bunker et al., 2015; Steigenberger, 2016; Wolbers and Boersma, 2013).

Same as for the C2S, the command and control processes in the different command and control centers (CCCs) deal with the receipt and prioritization of emergency calls, and the coordination and dispatching of assistance to the emergency locations. There are several challenges due to the work in the CCCs, using Emergency Medical Dispatch as an example; complications arise due to incomplete and uncertain information from different sources, multiple calls on both the same incidents or incidents occurring simultaneously, locating and controlling resources between different incidents and thus making effective decisions; all combined with time pressure (Wong et al., 2005).

2.3 Information sharing and collaboration

Information sharing is defined as "exchanging or otherwise giving other agencies access to required information" (Dawes, 1996, p. 382). Using information and communication technology (ICT) as a platform for collecting and sharing information is essential for managing today's emergency operations. Several barriers prevent the right information from being shared with the right receiver at the right time (Schraagen and Van de Ven, 2011). For example, different stakeholders performing the various emergency response tasks at different C2S are geographically spread and cannot communicate face to face. Being able to collect and further share critical information with other EMOs promptly is a key component in executing collaborative response activities, and ICT plays an important role. Critical information in this context includes "information about lifesaving needs, the status of critical infrastructures, such as transportation, utilities, and communication systems, and the status of critical facilities including police, fire service, medical providers and voluntary groups" (Firdhous and Karuratane, 2018, p. 712).

Multi-organizational information sharing across the different C2S during emergency response operations requires different IS for the development of a shared and updated COP and building a common situational understanding between the involved stakeholders.

A high volume of research is related to how technology influences and supports emergency response teams, their workflow, and collaborative work (e.g., Cobb, 2014; Liu, 2014; Riebe, 2021). Most IS for collaborative decision-making in EM are developed to enhance stakeholders' SA (Mohsin et al., 2016).

There are different terms for the use of technology for managing emergencies.

(1) Emergency management information systems must assist the people responding to crises, disasters, and catastrophes and "support the coordination of efforts of a great number of organizations and individuals, many of them unfamiliar with the others, in the response situation of extreme urgency and under immense psychological and societal pressures" (Van den Walle et al., 2014, p. ix).*(2) Crisis informatics* is a multi-disciplinary field "concerned with the ways in which information systems are entangled with socio-behavioral phenomena connected to disasters" (Soden and Palen, 2018, p. 162).

(3) Information and communication technology (ICT) for crises/EM includes

> "various ICT tools, such as geographic information systems (GIS) and global positioning systems (GPS), are widely utilized in emergency management to inform decision-making, to facilitate information sharing, to enhance the quality of communication, to engage citizens and communities, and to coordinate collaborative efforts" (Hu and Kapucu, 2010, p. 325).

As can be observed, the terms overlap and seem to concern many of the same topics.

Aman et al. (2012) identify seven categories of tasks and actions that take place when EMOs are managing emergencies, which represent the ICT application areas in EM: communication, event detection and assessment, warning, GIS support, training, navigation, and evacuation.

2.4 Common Operational Picture (COP)

The literature refers to a COP as important for decision-makers to make better decisions in coordinating resources and for responders working on the incident scene through the different stages of an emergency event. The literature also describes a COP as a checklist of the characteristics in a certain situation within a geographical area, but if it is a process, a product, or an operating environment seems to be indefinite (Wolbers and Boersma, 2013). A COP is further characterized as a display of relevant operational information, such as positions, infrastructure, and different resources (Karagiannis and Synolakis, 2016). Geographical information is important in a COP because a large amount of the included information has a geospatial location (Luokkala et al., 2017).

A COP is also characterized as

> "essential for clear communication and coordination of actions among emergency response organizations. This means achieving a sufficient level of shared information among the different organizations and jurisdictions

participating in disaster operations at different locations, so all actors readily understand the constraints on each and the possible combinations of collaboration and support among them under a given set of conditions". (Comfort, 2007, p. 191)

For addressing the need for communication and coordination among the different organizations, Comfort (2007) introduced a framework based on the factors that involve the chain of actions by all stakeholders in the three-tiered C2S (Khorram-Manesh et al., 2016). These factors are introduced in table 2 as the 4Cs of a COP (Comfort, 2007, p. 191).

Table 1: The 4Cs of a Common Operational Picture (Comfort, 2007)

4Cs	**Descriptions**
Cognition	Provides the initial content and activates the link to the processes of communication, coordination, and control. Capacity rests on a clear mental model (see section 3.1.4) of how the system should work.
Communication	Is the ability to share meanings (such as goals and missions) among the involved stakeholders and find new ways to solve problems.
Coordination	Depends on effective communication for developing a framework for common action and achieving shared goals. The involved must voluntarily align their activities for adaptive performance.
Control	Is the capacity to focus on critical tasks and actions toward shared goals by common knowledge, skills, and mutual adjustment of actions to fit the evolving situation.

2.5 Multi-organizational EM exercises

It is important to be aware of why the stakeholders in EMOs need to practice, what to practice, and how to plan for learning in the exercise (Bjelland and Nakstad, 2018).

Ford and Schmith (2000, p. 196) define learning as "a relatively permanent change in knowledge, skills and/or attitudes produced by some type of experience" that enables stakeholders to transfer elements such as knowledge,

skills, and attitude into their job. For building expertise, knowledge depth is important. For example, stakeholders may have many similar experiences and may have been exposed to many comparable learning situations, and still, one person may far outperform the other. Expertise depth comprises highly proceduralized and principled knowledge, well-organized and structured mental models, and well-developed self-regulatory systems (Ford and Schmidt, 2000, p. 197).

Many exercises can be very resource-intensive, both in terms of cost and time. Extensive multi-organizational scenario-based exercises (i.e., building on previous experiences or risk analysis) are often focused on challenging scenarios rather than basic skills (Bjelland and Nakstad, 2018). However, several studies have demonstrated that it is possible to train teamwork-related knowledge, skills, and attitudes using cost-effective alternatives (Morey et al., 2002). This is an important element to consider since repeated interactions provide in-depth learning, which again develops well-organized metal models and long-term behavior.

The decision-makers during emergency response have to make decisions by intuition and/or reasoning. Educated intuition (Hogarth, 2001) is developed by growing experience through training. Simulation and training for different scenarios facilitate the identification of shortcomings, strengths, and weaknesses for decision-making in stressful environments, both on an individual and team level.

Most stakeholders within the different EMOs prefer to work alone or perform their own tasks side by side rather than across organizational boundaries, which results in a lack of collaboration, communication, and mutual understanding at all C2S (Berlin and Carlstrøm, 2011). Training for the 4Cs must recognize that the 4Cs have both cultural and structural implications, and learning happens more culturally than structurally. Khorram-Manesh et al. (2016) identify eight well-documented practices for training decision-making: (1) Common seminars during training for common reflections and analysis; (2) Comparing rules, procedures, and roles; (3) Focus on collaboration and common DM; (4) Simple scenarios can prepare for complex events; (5) Pre-clarification of roles; (6) Testing different strategies for collaborative DM; (7) Identify mistakes in the DM; (8) Train in scenarios that challenge collaborative DM.

Building shared mental models (SMM) through training will aid decision-making and adjust the stakeholders' behaviors based on predictions about the collaborating stakeholders' future activities and actions. This is the foundation for developing common situational understanding.

Exercises must be designed and conducted in well-thought-out training environments; however, evaluation and learning are important factors and should always be part of an exercise (Grunnan and Fridheim, 2017).

Related to EM training, the concept of assessment is to enhance organizational learning related to capabilities, capacity, and materials that contribute to effective EM and DM (Sinclair et al., 2012). Examples are post-exercise debriefs for providing a critical review of the exercise as a whole and reflections on the scenario. Training assessment incorporates two concepts: monitoring and evaluation.

Monitoring and evaluation can be used to monitor, measure, and assess performance after exercises for quality improvement. Monitoring focuses on to what degree the responsibility and progress comply with the results (Sinclair et al., 2012). Evaluation is a method for comparing actual results with intended goals, identifying weaknesses in the response, summing up lessons learned, and providing a foundation for future training needs (Gossip al., 2017; Sinclair et al., 2012). Further, a goal is to generate new knowledge and understanding that can be implemented in the organizations in focus (Alkin and Taut, 2003). Weiss (1999, p. 469) states, "The overall aim of evaluations is to assist people and organizations to improve their plans, policies, and practices." However, it has been documented that lessons have not been learned from several major incidents (e.g., Hurricanes Katrina [2005], Gustav [2008], and Ike [2008]) or when new crises occur (such as the H1N1 pandemic [2009–2010]) when it comes to revising procedures after identifying potential for improvement (Savoia et al., 2012). This also applies to large full-scale exercises (Gossip, 2017).

2.5.4 After action review of multi-organizational exercises

The fundamental components of the after-action review (AAR) are feedback, reflection, and discussion. Further, it brings together key stakeholders focusing on collective learning and challenges, as well as identifies and documents lessons learned (Copper et al., 2020).

The AAR is traditionally a team training intervention that aims to enhance team performance. The AAR method is highly effective, and its effectiveness increases if the following two characteristics are involved: (1) task, training, and criteria levels are aligned to the team (for example, goal setting and team tasks) and (2) the use of objective performance review media (i.e., media that do not rely on stakeholders' memory, such as video records) (Keiser and Arthur, 2021). The AAR process can either be facilitated by a content domain expert or be self-led. Mainly, the expert-led approach seems to be more effective because it helps to focus on the important elements of the training and is more structured (e.g., Smith-Jentsch et al., 2008; Tannenbaum and Creasoli, 2013).

3 Related Research

I started the project with a literature review to gain an overview of the emergency management domain, with a special focus on the chosen theories (see chapter 4), the response phase of EM, multi-organizational emergency management, use of information systems and technology support in EM, and COP. This review formed the basis for formulating the problem definition and the research design for the dissertation project. An extended literature review was conducted throughout the project as the RQs and research papers were being developed.

3.1 Multi-organizational EM in the response phase

In the EM of complex events, the need for rapid response is important to limit the damaging consequences to people, property, and the environment. This dissertation project considers the response phase for investigating, explaining, and suggesting solutions for the problem of information sharing and building common situational understanding in complex events.

The response phase has a high degree of dynamism and uncertainty (Santos et al., 2008). The most important characteristics for assessing the impacts of a disaster are its speed of onset and availability of perceptual cues (such as wind, rain, or ground movement). These factors affect EMOs in preparing and completing emergency response actions and in determining the extent of casualties and the degree of damage to the environment (Lindell and Prater, 2003). These critical cues are the beginning of the development of SA. A lack of such critical cues is a limitation for the response, and there is a need for the development of systems for key information structures (Valecha, 2019) and for sharing this information in an early EM phase. In this dissertation project, this need is addressed by discussing how to share identified key critical cues by using a window report structure (Borglund, 2017) and a heuristic rule developed based on the empirical data.

The main RQ and SQ3 in this dissertation concern collaboration practices and how stakeholders develop SA and COP. This includes what specific characteristics that make the work in the response phase unique (Orasanu and Connolly, 1993). The time-critical aspect is related to the urgent need for first responders to physically intervene (Burke and Hendry, 1997) and, further, the uncertainties and ambiguities caused by incomplete information (Klein, 2000). A quick response is dependent on team-based collective actions (Endsley et al.,

2003b). Since there are various EMOs involved, a dynamic situation can lead to changing and sometimes competing goals (Endsley et al., 2003a). In addition, the organizations involved work on different timescales (Rasmussen et al., 1991), which depend on their roles and responsibilities in the emergency response operation (Fredholm, 1997).

Because of the time-critical and sometimes conflicting conditions in the response phase, the initial EM is often inadequate, and the stakeholders in different EMOs are unable to make appropriate decisions (Son and Peña-Mora, 2008). The decision-making process is often a challenge and cannot be compared to rational decision-making that exists in many other domains (Endsley et al., 2007). The main content of decision-making in the response phase of complex EM include environmental analysis, the determination of emergency priorities, emergency preparedness plans, implementation, and feedback adjustment (Zhou et al., 2018). Human mental models provide the basis for what kind of plans and actions the stakeholders will select for a specific scenario, which is the foundation for human decision-making. The stakeholders need to learn about their mutual information requirements to support the information sharing processes (SQ1 and SQ2) which aids the stakeholders to make proper decisions in multi-organizational EM.

3.1.1 Challenges in the response phase

Summarizing lessons learned from research on emergency management, Boin and Heart (2010) identify different challenges of the strategic, tactical, and operational C2S in the emergency response phase.

In the strategic C2S, several stakeholders (such as political officeholders, agency leaders, and other public executives) experience the following recurring challenges:

1. *Sensemaking* in time-critical and confusing environments with limited and often contradicting information
2. Providing *meaning-making* to the public of what is happening, why, and who is responsible
3. *Making strategic decisions* during conditions of time pressure, uncertainty, and collective stress

4. Ensuring effective *coordination* of communication and collaboration among existing and ad hoc networks of different EMOs
5. *Circumscribing* emergency support, both in terms of nature and duration
6. *Consolidating* society from the response mode to the normal state, as well as paying attention to the areas that need long-term services
7. Providing *account-giving* to the pre-emergency debate and juridical inquiry so that responsibilities are clarified and accepted and destructive blame games are avoided
8. Ensuring the involved EMOs and systems are *learning* in the aftermath of the emergency and drawing evidence-based reflective lessons for their future performance (rather than politics-driven, knee-jerk ones)
9. Helping society to *remember* the traumatic experiences for all involved (the community should "never forget," such as 9/11 and the terrorist attack in Norway on 22 July 2011)

The stakeholders in the tactical and operational C2S (such as incident commanders [ICs] and operation managers) experience the following recurring challenges:

1. Making *diagnoses and decisions* regarding the situation with time pressure and incomplete information, choosing a sensible response approach, and continuously updating plans because of changing circumstances or additional information becoming available
2. *Mobilizing and organizing* the necessary operational resources to meet the demands of the situation
3. *Sharing accurate, timely, and actionable information* with other EMOs within the crisis response structure
4. Making sure that the *coordination and collaboration* with different EMOs are effective and sustainable

The strategic C2S does not involve the same detailed knowledge as the operational and tactical C2S, which is clear when considering the abovementioned challenges. For example, when making strategic decisions, it is important to not be distracted by details and lose sight of the overall picture. Further, for the learning aspect (as described in the eighth challenge of the strategic C2S), it is crucial to have systems for reviewing what actually

happened. However, it can be hard to provide solid evidence-based lessons in the aftermath of a complex emergency. The challenges of the operational and tactical C2S are affected by the need for sufficient SA, COP, and common situational understanding.

3.1.2 Training and exercises for improving common situational understanding

Stakeholders in EMOs can attain readiness by participating in exercises and managing emergencies. For example, Fast et al.'s (2016) study of training effects related to emergency response showed that stakeholders with higher levels of training initiate a significantly higher proportion of emergency response activation. In the EM context, learning and training take place in classroom settings, by tabletop exercises, and in simulated environments. However, some basic elements must be considered for facilitating effective learning so that the stakeholders can function effectively when responding to emergencies and successfully collaborate with other organizations.

Participation in exercises is, of course, the most preferable way for gaining expertise. However, there are no guarantees that stakeholders learn after exercises, and many have experienced limited learning benefits (Berlin and Carlstrøm, 2014). Cross-organizational exercises are important in EM; however, research shows there are many associated challenges (e.g., Andersson et al., 2014; Bergstrøm et al., 2019). For example, the different organizations involved may find it difficult to understand each other's capabilities and limitations, actions, logic, agendas, legislation, and hierarchical levels (e.g., Lee et al., 2009; Perry, 2004) and to learn from similar events in other organizations (Crichton et al., 2009). Several of these challenges are related to a lack of SMM, which is crucial for developing a common situational understanding.

Ideally, stakeholders should be properly taught and trained by experts and should practice regularly to perform accurately when required (Miller, 2020). Memory is not fixed at the moment of learning. For example, one can repeat an address or a description of a picture several times for a short period. The stakeholder would then remember the information for a limited time in their working memory (WM). However, to push information into the long-term memory and thus

develop well-organized mental models, the basic facts should be exposed to stakeholders repeatedly, and a detailed elaboration of stakeholders' impressions should be noted. This is called elaborative rehearsal and should be started as soon as possible after an event/exercise for successful learning for all types of memory (Medina, 2014). Studies have shown that repeated experiences in a certain context or environment serve as a foundation for a person to develop expectations that can form the projection on future status (Endsley, 1995). This is important for stakeholders' self-regulation skills, which include the ability to know the appropriate strategies in different contexts (Ford and Schmidt, 2000).

In the cognitive psychology domain, it has been established that the most effective learning environments are those that are problem centered (Mayer, 1992). Merill (2002) describes five stages of how to prepare efficiently: (1) learning, (2) practice, (3) practice during pressure, (4) performance, and (5) performance during pressure. Stakeholders can "drill a skill" by learning the theoretical elements and can then practice and perform during stressful environments. Repeating this will result in elements being performed more or less unconsciously because the information is stored in the somewhat stress-resistant long-term memory. Practice allows stakeholders to experience the reality by simulation (imitation or training of a situation or process) and thus make controlled errors and understand what is possible to do and what is not (Salas et al., 2009). Simulation is also a method that trains mental models (Cannon-Bowers et al., 1993). Stakeholders in EMOs in the three-tiered C2S have a huge variety of tasks they must solve during stressful conditions. As stated above, the need for repetition is related to how knowledge can be stored in the WM and long-term memory. Stakeholders must be able to test their knowledge and skills in a safe environment, where failure does not result in severe consequences. Environments for repeated scenario-based training for multi-organizational collaboration are needed (Khorram-Manesh, 2015).

Blended learning increases knowledge when teaching emergency preparedness (Lateef, 2010). This combines two or more teaching methods, such as ordinary lectures (i.e., explanation-based learning) and practical exercises (i.e., experiential and/or skill-based learning) (Boin et al., 2017; Khorram-Manesh, 2015). The outcome of such blended learning also depends on collaborative team skills (Beaubien and Baker, 2004).

Several issues are related to the evaluation of collaborative exercises. First, different decision-makers operate with different understandings and knowledge about situations, and it is hard to gain an objective evaluation of full-scale exercises (Gryth et al., 2010; Ju and Wang, 2012). Also, even if the involved actors are aiming to achieve a collective perception, it is most likely that they transfer their perspectives to situations based on their professional standpoints (Imoussaten, 2014). There is, however, continuous development of several evaluation methods that aim to overcome the problems with the evaluation of multi-organizational exercises with several decision-makers. An example is the after-action review (AAR) (Allen et al., 2018), also commonly called debrief, which is a method performed by the involved stakeholders themselves after the exercise.

The evaluation after multi-organizational exercises relies on textual sources (such as reports) and interviews. However, there is a lack of real-time communication (the actual message exchange and situated perceptions) and objective media for evaluations, which makes it difficult to get an objective overview of the detailed situation. For example, audio logs (ref. thesis Article #1) and SMS data collection (ref. thesis Article #2) can be important supplements to video records. This is an important element because of the different perspectives during and after the exercise and because of the limitations in human memory systems. However, the quality of the media for objective information is important – for example, cameras that capture the complete range of trainee behavior (Santos et al., 2021). The evaluation of highly complex tasks cannot solely on draw the benefits of objective media, as it is important to cover all relevant aspects, including participants' perspectives (Ellis et al., 2010). Thus, an evaluation that encompasses both subjective and objective performance reviews seems to be most beneficial after multi-organizational exercises. This increases the probability of the results leading to improvement (Gryth et al., 2010).

The literature mainly recommends developing performance indicators taught and implemented during pre-disaster preparations, such as training scenarios. For example, performance indicators in the AAR increase the underlying elements of effectiveness and provide a more focused discussion (e.g., Smith-Jentsch, 2018; Tannenbaum and Creasoli, 2013). Further, a structure limits off-task discussions

that can distract the stakeholders involved and frees up cognitive resources for the important elements (Smith-Jentsch et al., 2008). The AAR seems to be a productive method for the participants' ability to learn from exercises and thus manage crises better.

3.2 Informations Systems in EM

The interest of IS scholars in EM is growing (Bonaretti and Piccoli, 2018). The IS developed for emergency response work are designed with a focus on C2S, which emphasizes concepts such as decision-makers, hierarchical organization of actors, vertical unidirectional decisions, and information flows (Landgren, 2007). However, the effectiveness of the systems is determined by factors such as interoperability across the EMOs involved, knowledge of use, infrastructure vulnerability, and system flexibility (Waring et al., 2018). Existing IS literature suggests that the adoption and utilization of ICTs in different organizations rely upon technological attributes, human factors, organizational culture and structure, and institutional factors (Hu and Kapucu, 2016).

The EM field has focused on the opportunities afforded by technological advances, such as decision-making, data collection, and information sharing, from a '*technology as a solution'* perspective. However, the complexity of multi-organizational EM challenges the IS scholars with the need for conceptual frameworks to drive studies of the complexity of information sharing in stressful environments (Allen et al, 2014).

Literature has identified four overarching practical concerns and goals for the use of IS in EM; (1) *understanding the situation, (2) deciding and acting, (3) collaboration among responders, and (4) engaging with and outreach to the public* (Fischer-Preßler and Bonaretti, 2022). This dissertation project concentrates mainly on the response phase and the ability of IS for supporting professional stakeholders in handling complex emergency events and includes the three first practical concerns and goals. Understanding the situation is related to SA where one of the goals for designing IS for training programs and handling emergencies is to provide stakeholders with SA. According to Endsley and Garland (2000), the challenge with SA is not necessarily a lack of information but the ability to detect what information is needed and when it is needed. SA

involves perceiving and comprehending large sets of rapidly changing data. For understanding the scope of the emergency the stakeholders must assess the situation using emergency management platforms (Yang et al., 2012). These IS will aid the stakeholders` situation assessment with the collection, sharing, and presenting of on-site information. The design of IS for EM must therefore consider human factors such as SA, because, from a socio-technical perspective several errors can occur from the interactions between the system and the stakeholders that operate it (Radianti et al., 2021). There can be devastating consequences if a decision is made in the context of degraded SA, and several factors can reduce one or more SA levels (Endsley and Jones, 2016). These factors are characterized as SA demons and classified into eight categories, each concerning one or more SA levels. Camblor et al. (2021) and Salotti and Suhir (2019) present the SA demons as follows: *Workload, fatigue, and stress* taxes the working memory (WM) and attention (Level 1, 2, and 3 SA), leading to a direct impact on performance. *Information overload* occurs when too much information can/must be processed (Level 1 SA) in a context involving attentional or time constraints. *Misplaced salience* concerns how a piece of data is presented in an IS (Level 1 SA) – for example, the IS is designed to maximize the operators' attention to it, while access to other more relevant information is being blocked. *Complexity creep* refers to systems that are too complex or so many that they slow down the perception and comprehension of the information and, thus, the ability to project future status (Level 1, 2, and 3 SA). *Errant mental models* result in misinterpretations of the situation and wrong projections of future status (Level 1 and 2 SA). *Out-of-the-loop syndrome* concerns when automated systems do not involve the operators before it is a problem (Level 1 and 2 SA). *Attentional tunneling* is when the operators' attention is locked on some data and they cannot switch between multiple data streams and exclude important information (Level 1 SA). *Requisite memory trap* concerns when the operators forget one of many subtasks because the WM that processes and holds data for Level 2 SA is limited.

Understanding the situation is interrelated with both decision-making, acting, and collaboration among responders. Decision-making and collaboration between the stakeholders are based on the stakeholders` understanding of the situation, thus their SA. In multi-organizational EM, the individual organizations hold data in separate systems (e.g., knowledge management systems and incident

management systems) which are accessed by stakeholders in the various control rooms. They will then make several decisions concerning e.g. resources and provide the operative units with contextual information provided by voice to voice (using a secure radio network) and data (using in-vehicle mobile data terminals) communication (Allen et al., 2014). IS for decision-making (decision support systems and intelligent agent systems) consist of computer applications that facilitate the stakeholders` decision-making by using communication technologies (for example radio networks and live video), documents, and models to identify problems and courses of action (for example the triple alert routines), and present recommendations for a specific context (Fischer-Preßler and Bonaretti, 2022; Yang et al., 2012). The triple alert routine is a communication-driven decision support system that enhances decision-making by enabling communication and sharing of information between several stakeholders from different EMOs. A typical data-driven decision support system is a GIS that visually represents geospatial data using maps (Yang et al., 2012).

A growing amount of research has in recent years been concerned with how IS can enable collaboration between emergency stakeholders. The lack of consistent data standards hinders efficient critical information flow among stakeholders (Chen et al., 2013). It is possible for the different EMOs to share objects, such as positions and text (for an example, see CIM in Appendix F), however, they traditionally operate in an organizational-specific manner which results in fragmentation of the shared objects (Allen et al., 2014). The heterogeneity of the IS results in a lack of interoperability (i.e. the technical capability of the systems to exchange information) and interrupts information flows (Chen et al., 2014). Also, the different perspectives between the involved EMOs, such as goals, rules, and norms, result in great contradictions and barriers to interoperability and information sharing exist. In addition, the work processes do not reflect a norm of sharing information with other organizations (Allen et al., 2014).

The growing interest of IS scholars in EM does not seem to be captured by the mainstream IS literature. Statements such as "*although we can assume that EMIS facilitates emergency management, little is known about the main functions of EMIS*" (Fischer-Preßler and Bonaretti, 2022, p. 2) document that the research presented in conferences with a dedicated focus on IS for EM conferences (such as ISCRAM and others mentioned in section 1.1) is not included in the

systematic literature reviews. Peer-reviewed conference proceedings should be an essential part of any bibliography concerning IS for EM, if not, the majority of specific research in this domain might be excluded.

This chapter has pointed to several problems due to information management and information sharing in the response to emergencies. To handle these problems, IS assist stakeholders by deploying a COP.

3.2.1. COP as a baseline for common situational understanding

Using specialized IS during the response phase of EM enables the involved stakeholders to build and maintain a COP. There are several characterizations of a COP identified in the literature, as summarized in Table 3.

Table 2: Characterizations of a common operational picture (Steen-Tveit and Munkvold, 2021)

COP characterization	**Reference**
(1) A COP can be a situation awareness system that refers to knowledge management systems for SA and decision-making.	McNeese et al. (2006)
(2) The term COP extends prior research on large group displays to describe a visual representation of tactical, operational, and strategic information intended to generate SA.	Hwang and Yoon (2020)
(3) A COP is a continuously maintained description of the situation and operational environment built from the received information and the conclusions based on it.	Norri-Sederholm et al. (2017)
(4) A COP incorporates information that enables situational information to be produced, visualized, and presented in such a way that all information is available to all the actors involved in the crisis response in real time.	Luokkala et al. (2017)
(5) A COP is a mental model of how a system works, guiding the application of a safety management system in everyday practice.	Aneziris et al. (2017)

(6) A COP as a display of relevant operational information, such as positions, infrastructure, and different resources.	Karagiannis and Synolakis (2016)
(7) A COP is created by an actor and consists of a selection of important parts of the available information, in the form of descriptions and predictions of what is going on, and related information as, e.g., resources, actions, prognosis, and perceptions.	Borglund (2017)
(8) A COP is a centralized information display system designed to establish team SA by presenting information gathered from various subsystems.	Baber et al. (2013)

Several researchers (e.g., Luokkala et al., 2017; Luokkala and Virrantaus, 2014; Turoff et al., 2004; Vescoukis et al., 2012) have defined requirements for a COP. A common feature of these requirements is that the COP must address the knowledge management processes more comprehensively and ideally include tools for selecting and combining situational information for creating narratives supporting the users to achieve all three SA levels (Luokkala et al., 2017). This is reflected in the research literature, where two perspectives of COP seem to be dominant: one perspective focuses on the opportunities for information sharing (COP characterizations 1, 2, 5, 6, and 8 in table 3), and the other perspective concerns the requirements for developing common situational understanding (COP characterizations 3, 4, and 7 in table 3) (Giaoutzi and Scholten, 2017; Steen-Tveit and Munkvold, 2021).

Treurniet and Wolbers (2021) found that the information coded in a COP is predominantly at the syntactic level (i.e., factual), and that the "warehousing philosophy" is presented in many academic discussions as an enabler of cross-organizational decision-making. The warehouse philosophy suggests that information can be collected, sorted, and exchanged in an accessible and univocal form. However, it is important to acknowledge that professionals from various EMOs may interpret similar information differently (Bunker et al., 2015; Wolbers and Boersma, 2013). Wolbers and Boersma (2013) thus argue that "a trading zone" for negotiation for developing collective sensemaking of information in a COP is necessary. The trading zone is described as "where the process of translation and negotiation takes place" (Boersma et al., 2012, p. 6),

and the involved stakeholders can negotiate interpretations and professional views of the situation.

The development of a common situational understanding concerns the sharing of additional and abstract information (for example, interpretations, and perspectives). Stakeholders must make sense of the situation and negotiate meanings, intentions, and plans. This understanding reconciles a range of perspectives, options, and changes that often challenge the stakeholders involved in the response to complex emergencies (Bunker et al., 2015). While serving as a baseline, the perspective of a COP as an information warehouse or a display of relevant situational and operational information is insufficient in this sense. For improving the management of information in complex emergency events, an understanding is needed of what information can facilitate the management in different contexts, which information is important for whom (Luokkala et al., 2017), how it should be presented, and in which phase of the EM it is to be used (Onorati et al., 2019).

The development of common situational understanding concerns abstract information – for instance, the human capacity to share a diagnosis of unexpected behaviors and problems quickly and accurately (Arciszewski and De Greef, 2011). These are capabilities that belong to the stakeholders' mental models and must be acquired through experience, exercises, and training. However, the learning potential from EM exercises is often far from fully utilized, and problems concerning the development of common situational understanding observed in emergency operations remain unmanaged afterward and reappear in the next exercises or real event (Borell and Eriksson, 2013). Therefore, teamwork-related knowledge, skills, and attitudes must be trained regularly through repeated interactions in multi-organizational exercises.

4 Theoretical perspectives

The IS discipline is relatively new, starting at the same time as the modern cognitive psychology domain (i.e., in the 1950s). Modern cognitive psychology involves the study of mental processes (e.g., perception, attention, problem-solving, and creativity) (American Psychological Association, 2020; Miller et al., 2020). When computers were developed and came into human lives in the 1950s, the concept of modern cognitive psychology arose. Psychological processes were compared to information management in IS. For example, computer memory is "location addressable, if the system is given a certain location it will return with the contents of that location" (Shiffrinn, 1969, p. 181). The knowledge from research on psychological processes is important for the theory of how humans perceive the environment and make decisions. This dissertation project concerns aspects of stakeholders' perceptions of the environment and decision-making processes related to EM supported by IS. The IS discipline concerns human, organizational, and computerized information-processing mechanisms. The UK Academy for Information Systems describes the technological, management, organizational, and social focus of IS with the following definition (Avison and Pries-Heje, 2005, p. 187):

> The study of information systems and their development is a multi-disciplinary subject and addresses the range of strategic, managerial, and operational activities involved in the gathering, processing, storing, distributing, and use of information and its associated technologies in society and organizations.

The IS discipline is thus an applied social science connected to the use and impact of technology (Avison and Pries-Heje, 2005).

In this dissertation project, theoretical concepts are chosen at different stages and used in lighter or tighter ways for making sense of the results as a whole. The SA model, including shared mental models, and the Normalization Process Theory were used as initial guides to design the data collection tools and further analyze the results. Theories on decision-making (RPD model and HB view) and sensemaking are used in the discussion in this dissertation as the coding process generated sets of categories, and these concepts were later connected to existing

theories. By combining theoretical perspectives with the results, more knowledge of the complexity behind multi-organizational EM processes is provided. The dissertation project employs an interpretive approach and acknowledges that constructs do not have absolute meanings because the meaning is attached to them by individuals. The selected theories mainly seek to uncover how individuals make sense of their world as a way of explaining their responses.

As introduced in section 1.4, the main theoretical lens used in this dissertation project is the SA model (Endsley, 1995), which is complemented with theories on SMM (Cannon-Bowers et al., 1993) and sensemaking (Weik, 1995), as well as NDM perspectives (Klein, 2008) and the heuristics and biases (HB) view of decision-making (Kahneman, 2011). Human memory plays an important role in SA because it stores and processes information. These are important mechanisms to consider for how to train effectively, how to develop mental models, and how new information is combined with the existing knowledge for supporting collaboration.

In multi-organizational EM, all these factors are interrelated and build upon each other for successful decision-making. The decision-making process involves stakeholders with different perspectives of a situation and different prerequisites for making decisions. Therefore, both agency-specific and collaborative procedures for EM must facilitate consciousness in the human decision-making process and make it suitable for the process of support it aims to contribute.

This chapter provides an overview of the chosen theories and concepts and presents how these are relevant to the research topic and the data collection and analysis conducted throughout this dissertation project.

4.1 SA and mental models

A substantial number of studies have pointed to SA as one of the key elements in EM (e.g., Dilo and Zlatanova, 2011; Endsley, 1995). SA is also among the most researched topics in the domain of human factors related to EM (e.g., Cak et al., 2020). SA can be viewed from an individual, team, or systems perspective.

There are different views on the foundations of the SA concept, whether it belongs to the psychology, engineering, or systems ergonomics domain and how

each of these domains describes SA and how it manifests itself (Stanton et al., 2010). For example, the first perspective is the psychological approach, which mainly concerns the human perception, knowledge, and understanding of dynamic tasks. Endsley's (1995) three-level model introduced in section 1.1 is perhaps the most well-known approach. This occurs only in the minds of people (e.g., Endsley and Jones, 1997) and is thus an individual psychological phenomenon. However, system design plays a role in the sense of to what degree it provides the needed information and in which form it provides it. Endsley's (1995) psychological approach will be further discussed later in this section.

The second perspective is the engineering approach, which focuses on physical phenomena and that SA is somewhat imbued in technology and displays. A definition from the military domain is "the ability to have accurate real-time information of friendly, enemy, neutral, and non-combatant locations; a common, relevant picture of the battlefield scaled to specific levels of interest and special needs" (TRADOC, 1994, cited in Endsley et al., 2000, p. 3). This view can be described as a COP where different elements of the operation are objectively presented in some sort of information system, such as a GIS. This SA perspective is also evident in the following definition: "Situational awareness is achieved by integrating a myriad of technologies to provide users with access to information based on their circumstances" (ESRI, 2008, p. 2). However, there are several factors to consider when arguing in favor of an engineering approach to SA – for example, information overload, poor interpretation, and the presence of nonrelevant information and false data (Bolia et al., 2017).

The engineering view of SA does not fit into this dissertation project because, in reality, stakeholders do not receive information from the technology itself but from the environment and the humans in it. Stakeholders simply use technology and applications to collect, share, and visualize information under the circumstances where it is possible. The human aspect, considered an important element in this dissertation project, is mainly out of the loop in the engineering approach.

The third approach is the systems ergonomics approach. This is also called distributed situational awareness (DSA) and describes how people work together and how information connects people and technology (Stanton, 2016; Stanton et

al., 2006). Technological development has made humans able to act more effectively in decision-making when operating in dynamic systems (Endsley, 1995). DSA combines the psychological and engineering views of SA and concerns the interaction between human and technological artifacts. However, since stakeholders interpret the same information differently, SA is developed as an individual process. Further, individual knowledge is continually updated based on experience (i.e., underlying cognitive functions) and the search for information within the environment. When managing the same emergency in a team (multi-organizational EM), the stakeholders have somewhat the same SA requirements (to varying degrees) since they are working on the same incident. The difference is that the SA requirements facilitate different perspectives, priorities, and actions due to the individual/organization-specific tasks. However, all involved organizations have the same overall goal: to save lives and limit damage. This requires effective collaboration, which again requires SMM that include awareness of collaborating organizations/team members' SA requirements and a current understanding of the situation. The DSA approach emphasizes the system approach to team SA, where the SA arises from the team members' interactions with each other and artifacts in the world (Stanton et al., 2006). However, high levels of individual SA are linked to high levels of performance in teams (Endsley, 2000).

4.1.1 Endsley's SA model

As stated earlier in this section, Endsley's model is considered an individual information-processing approach and is typically found in cognitive psychology (Stanton et al., 2010). An interpretation of SA that emphasizes cognitive psychology is as follows: "the combining of new information with existing knowledge in working memory and the development of a composite picture of the situation along with projections of future status and subsequent decisions as to appropriate courses of action to take" (Fracker, 1991, cited in Salmon et al., 2007, p. 408).

The above definition emphasizes how stakeholders combine existing knowledge and experience into the individual development of SA, coupled with the dynamics in the environment. Time itself is thus an important factor to consider regarding each actor's SA because SA is connected to how the situation evolves (Fracker, 1991). One of the contributions of this dissertation project is addressing

the limited knowledge related to the relevant information needs (Seppänen and Virrantaus, 2015) required to create good SA in the management of complex events. Thus, the time dependency of the information should be determined in more detail (Van den Homberg et al., 2018) – which in this dissertation project is connected to what information can provide stakeholders with SA and how IS can provide the needed information, in what form, and at what time.

The analysis of the audio logs in Article #1 revealed the state of SA in different stages of the operation and demonstrated the importance of individual SA for being able to share relevant information. For example, the information exchanges combined with the timeline illustrated how stakeholders shared critical cues (level 1 SA), requests and situation reports (level 2 SA), and planning and projections (level 3 SA) during the response (see Article #1, Appendix A and section 7.3/figure 11 for elaboration). This particular study concerned the use of a secure radio network including how the stakeholders utilized a common call group for information sharing. In Article #2, an SMS-based survey method was used for investigating the different levels of SA during a field exercise. The answers enabled us to capture near real-time information during different phases of the response and analyze whether this can make us better positioned to identify what works well and what does not work in the process of establishing SA.

In Article #3, the SA model is used to discuss an information sharing structure where the SA levels represented the specific situational information being reported. Additionally, the results demonstrated that different SA elements (such as location) could benefit from being shared using visualization tools instead of radio networks or other tools for verbal communication. See Appendix B for the questions regarding SA levels.

In Articles #4, #5, and #6, the SA model is used in the discussion sections for illustrating the different human information-processing mechanisms of the information elements throughout an emergency response.

Key challenges in the emergency response phase are assessing the existing situation, collecting accurate and relevant data from the incident scene, analyzing the data, and transmitting the data to the right personnel at the right time (Son et

al., 2008). SA is crucial for making effective decisions and for successful performance (Endsley and Garland, 2000). However, SA is not always sufficient for effective decision-making since factors such as experience, training, organizational and technical constraints, and strategy also have an important impact. In this dissertation project, the results from the Mandal exercise (section 6.8) illustrated that experience and training, in addition to SA, can improve decision making because the stakeholders understood each other's patterns of actions and relevant insights into what resources the collaborative organizations hold. Further, organizational and technical constraints were low as the communication in the radio network was streamlined and relevant, and the stakeholders thus were more comfortable with the use. Figure 4 shows how SA fits into the overall individual process of decision-making, involving human factors and organizational and technical constraints. First, the environment consists of elements that can be captured by human senses and information system displays, which is the basis for forming stakeholders' SA. The identification of the important elements for a specific stakeholder in a certain context is important for developing a high SA, as most elements are not relevant for all stakeholders involved. Endsley (1995) suggests that one should predetermine relevant elements for different contexts. Elements provide the different stakeholders with different SA because of the individual differences in information processing influenced by experience, capabilities, training, and individual preconceptions. Also, individuals can develop automaticity of cognitive processing below conscious awareness, and this can benefit SA by overcoming limited attention capacity (Endsley, 1995). Other environmental factors that influence SA are stress, workload, and situation complexity.

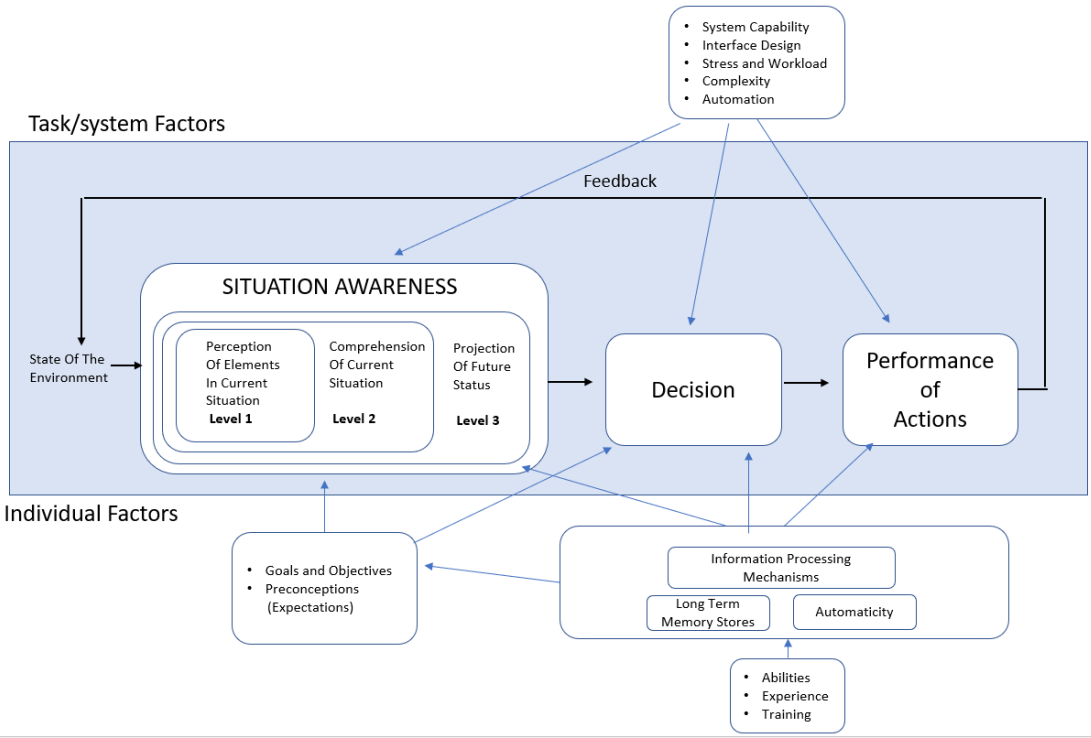

Figure 4: Endsley's model of situation awareness (Endsley, 1995, p. 35)

One of the key concepts of the three-level model of SA is that different environmental elements are mapped into the individual mental models, which again facilitate the development of SA. Since mental models are formed by experience, the stakeholder will have the ability to direct attention to the critical cues in the environment (Level 1 SA), integrating the cues to aid understanding of what they mean (Level 2 SA) and then generating a possible future status (Level 3 SA) (Salmon et al., 2008).

One of the main reasons why this theory is used in this dissertation project is that Endsley's model links the three levels to several psychological mechanisms. Based on this, it is possible to understand how individuals develop SA and what it comprises (Stanton et al., 2017). SA is thus a descriptive label for a behavioral phenomenon, however, it cannot be identified as an objective state. Information processing of critical cues (e.g. important information as identified in Articles #3 and #6) must be connected to the respondents' understanding of the world (i.e. a cognitive phenomenon) and reflects that SA requires a more holistic approach to human performance. There are SA requirements in different emergency contexts that can be understood by the stakeholders if they share (nearly) the same meaning of the environment in terms of EM elements (tasks, tools, goals, etc.).

These SA requirements can be the foundation for a discussion about which IS that are appropriate related to information collection (e.g., live video, GIS, triple alert routine) and information sharing (e.g., secure radio network). Various IS can provide a good representation of different SA requirements and therefore aid the stakeholders' development of SA.

Table 4 provides a brief description of the psychological mechanisms in SA. Mental models, decision-making, and sensemaking are further elaborated in the next sections because these elements are important for not only individual SA but also factors that need to be included in a model for a common situational understanding.

Table 4: Situational awareness mechanisms (Endsley, 1995)

Mechanism	**Description related to SA**
Perception	Expectations and knowledge of elements in the environment, facilitated by memory, affect the speed and accuracy of perception of information. Long-term memory forms mental models, which immediately act in the perception process and form the basis for higher SA levels.
Attention	This involves information sampling – selecting important elements (improving Level 1 SA) related to goals based on memory (long-term and working memory).
Memories	A human's active information processing occurs in the working memory. New knowledge combines with existing knowledge and forms Level 2 and 3 SA. Long-term memory involves schemata, which are frameworks/conceptual frames that influence individuals' interactions with the environment (see the explanation of scripts below).
Goals	SA is linked to a person's goals, and the goals are the basis for most decisions in dynamic environments.
Plans	Plans are devised for reaching the goals using projection (Level 3 SA).
Mental models	The concept of a mental model is related to the concept of schemata. A mental model can facilitate all three SA levels by mapping critical cues (Level 1), matching patterns (Level 2), and generating scenarios (Level 3).
Scripts	A script is a type of schemata that provides a sequence for appropriate actions for different types of task performance. This results in automatic actions in different situations based on the associated script.
Decision-making	SA forms the basis for decision-making.

4.1.2 Mental models

Having a well-developed mental model enables a person to explain and predict the surroundings (Rouse and Morris, 1986) – as a mental model is a framework, or pattern-matching mechanism, that they carry in their mind. Several studies concern pattern-matching mechanisms that connect the information stored in the long-term memory to a quick understanding of a certain context (e.g., Basulto, 2013; Chen et al., 2000; Shugen, 2002). The person's actions would then follow up on the information in their memory and adapt it to the specific situation they must act upon. This mechanism can be conscious or can occur more or less immediately because the person quickly matches the situation to the patterns. If they find a clear match, they can act based on what seems most typical to do in such a situation (Klein, 2008). From a constructivist perspective, the stakeholders do not acquire the representation of truth but rather construct viable knowledge via education, experiences, training, and interactions with other stakeholders. The mental models consist of viable knowledge that is based on everyday experience and is gradually modified to become consistent with culturally accepted views (Ritchie et al., 1997).

Endsley (1995, p. 44) describes three elements in a well-developed mental model:

1) Having knowledge of the relevant cues that can be used for attention direction and classification
2) Integrating the elements for understanding what they mean
3) Using pattern-matching mechanisms for projecting a future status based on the dynamics of the current state

If stakeholders have, based on training, education, and experience, well-developed mental models, they can recognize and link critical cues, thereby forming an understanding of what these separate information elements can mean. Experts have well-defined mental models that enable them to see connections between seemingly disparate pieces of information (Ford and Schmidt, 2000). Further, stakeholders' mental models should then be able to project what could happen next. For example, a firefighter observing smoke in a certain color and a specific smell can understand what kind of situation that must be acted on.

Further, the firefighter can act proactively because they can project what this particular situation can result in.

4.1.3 Shared Mental Models (SMM)

Salas et al. (2005) argue that the coordinating mechanisms for effective teamwork are the development of SMM, mutual trust, and engagement in closed-loop communication. They define SMM as "an organizing knowledge structure of the relationships among the task the team is engaged in and how the team members will interact" (ibid p. 560).

An SMM is a psychological construct that presents the mental models represented by all team members. While an individual mental model is a cognitive display of the structures that form the basis for interaction (Resick et al., 2010) and somewhat explains an individual's decision-making, an SMM is a shared comprehension between all individuals involved in a team regarding concerns such as task, performance, and interaction (Cannon-Bowers and Salas, 2001). Stakeholders that have developed SMM can often anticipate other team members' needs and proactively help each other perform their tasks (Yen et al., 2006), which are important elements in teamwork.

Cannon-Bowers et al. (1993) argue that team members have four levels of mental models of tasks and the team (table 5).

Table 5: Four levels of mental models

SMM type	Description
Resources/Equipment/Technology/ICT	This concerns how stakeholders understand the operation and how the technology interacts with their tasks, as well as the technology's opportunities, limitations, and failures (Cannon-Bowers, 1993; Thomas and Bostrom, 2007).
Job/Task	Stakeholders must understand their tasks and how to solve them, what information is important, how to combine information, required

	procedures, and how elements in the environment affect task performance (Cannon-Bowers, 1993).
Team Interaction	Stakeholders must understand their roles, tasks, contributions, who needs what information, and how to interact with team members, monitor their behavior, and when to help/back up behavior (Cannon-Bowers, 1993; Salas et al., 2005).
Team	Stakeholders must be familiar with other team members' key elements, such as knowledge, abilities, preferences (Cannon-Bowers, 1993), goals, resources (Norri-Sederholm et al., 2017), and each other's modus operandi (Steen-Tveit et al., 2020).

When training as a team, it is important to enhance the stakeholders' confidence both as a member of a team and as an individual actor (Morgan et al., 2013). Stakeholders share mental models when they have an understanding of their own and others' operational tasks (Jonker et al., 2010). Successful shared mental models have three important criteria that optimize teamwork. First, based on correct assumptions, the team members have an accurate reflection of the current reality (hence SA). Second, the team members have a joint agreement on what their goals are and how to achieve them. Third, the team has a description/procedure of how they must collaborate to achieve goals (Edgar, 2021). Research shows that even during stressful environments with reduced opportunities for communication, effective teams can maintain high performance if the team has a common understanding of the task (Espevik, 2006). The literature presents the mechanisms that allow such high performance as the concept of SMM (e.g., Bolstad and Endsley, 2003; Cannon-Bowers et al., 1993; Mathieu et al., 2000).

The data collected in the Mandal model exercise (section 6.8) aimed to investigate the development of SMM after implementing short collaboration activities for the last decade. The questions asked were related to the elements of SMM and successful teamwork (see Appendix B, question no.8). The results also supported a former study of Norwegian submarine attack crews (Espevik et al.,

2006) that showed that the need for explicit information sharing is lower in teams with a highly developed SMM (Kleinman and Serfaty, 1989). The teams that had developed SMM decreased the information flow, and the members showed less physiological stress reaction. Thus, teams with members who did not know each other had not developed SMM, communicated more, requested more information, and discussed more on how to solve problems. This shows that guidelines/procedures and skills are not enough for the development of a common situational understanding and effective team performance. Stakeholders must develop SMM together with other stakeholders.

SMM in ICT-supported teams

Over the past few years, the rise of virtual teams has been a result of the vast investments in communication platforms and networks (Aritz et al., 2018). Also, due to the ongoing COVID-19 pandemic, virtuality's effect on teamwork is now an increasingly important part of work organizations. Using virtual teams increases different organizations' possibility of utilizing skills and expertise regardless of where the stakeholders are located. Further, it allows stakeholders to overcome time and distance constraints. A virtual team will typically communicate and coordinate activity through some sort of ICT (Gibson and Cohen, 2003), such as video conference systems, file sharing systems, radio network communication, social media, email, or texts. Article #5 in this dissertation project investigates how emergency dispatchers can utilize the video function to more efficiently build a SA than through voice or text alone, and how this is incorporated into the response process. The results documented that the interpretation of the severity of various situations can be quite different by using live video, and providing contextual information can ease communication. Using such live video should be considered as an opportunity for facilitating SMM by acting as a virtual team.

The concept of SMM embraces all aspects that influence communication (Cannon-Bowers et al., 1993) and should therefore consider SMM established through ICT-supported virtual teams (Thomas and Bostrom, 2007). When Cannon-Bowers et al. (1993) introduced the resources/equipment/technology/ICT SMM (see table 5), they considered it stable and not important for team functioning. Now, with the evolving use of different ICT functions, it cannot be suggested as a stable function anymore. The

development of SMM in ICT-supported virtual teams is worth including as an important element for team functioning (Müller and Antoni, 2020).

Research on virtual teams suggests that the stakeholders in such teams often experience process losses compared to stakeholders who engage in face-to-face teamwork, as SMM developed face to face are crucial for the success of a team (Santos et al., 2015). The quality of communication between stakeholders is affected by what media they are using. Media richness theory (Daft and Lengel, 1983) suggests that commonly used media in organizations work better for certain tasks than others. Media that do not include face-to-face interactions can result in ineffective information sharing and communication between team members concerning work-related tasks (Bell and Kozlowski, 2002). Interactions between team members are influenced by the absence of face-to-face interaction, as some of the cognitive structures are most likely to be different in virtual communication compared to face-to-face communication – for example, the remote understanding of the overall task that has to be solved (Redlich et al., 2017; Schmidtke and Cummings, 2017).

4.2 Decision-making in emergency response work

As an interpretive researcher, I am a part of the research setting and my previous experiences as an emergency dispatcher made me better equipped to understand what I observed. An example is the theories of decision-making related to the use of procedures both for data collection and decision-making in emergency response (e.g. providing various measures and controlling the operative unit's fleet). The discussion between the role of expertise and decisions made based on biases was highly present during my time as a practitioner, however, the discussion was not connected to any formal theories. The data collected in this dissertation project suggested that different procedures used in practice apply to the theories on the RPD model and HB view on decision making.

The role of expertise in decision-making is frequently discussed in several high-consequence environments, such as fire and rescue services (e.g., Curnin et al., 2020; Okoli et al., 2016), emergency medicine (e.g., Farmer and Higginson, 2006: Wright et al., 2018), and the military domain (e.g., Johnson et al., 2014; Kaempf et al., 1996). The research shows that experts can make decisions based

on expert intuitions, which are based on previous experiences and recognitions of situations and are thus well-developed mental models. Expert stakeholders bring a range of relevant experiences into the practice, influencing their cognitive processes that facilitate decision-making. However, several stakeholders must make decisions without well-developed mental models due to the lack of experience and familiarity with situations and time constraints. In addition, in multi-organizational EM, several stakeholders must collaborate to reach the same goal, and experience influences the integration of relevant procedures (Nibbelink and Brewer, 2018) – which, in this case, are for individual and collaborative decision-making. Nibbelink and Brewer (2018) found in their study of nurses that the use of procedures for experts is useful in unfamiliar situations, and for novices, the procedures supported decision-making in general.

The respondents in this dissertation project were asked what influences their decisions and how they use procedures concerning this (Appendix B, question no. 4). The results are discussed based on theories on decision-making. For example, Article #4 discusses how the triple-alert routine can be seen as an example of how a collaboration structure considers the decision-making model. Article #5 concerning the use of live video for data collection discusses the literature on decision-making and how dispatchers need additional information while collecting critical cues and thus have to activate the cognitive reflective system to address the situation. A discussion on how to make decision-making processes as effective as possible, with or without the use of procedures, must take theories on decision-making and cognitive processes into account.

4.2.1 The HB view

Researchers have divided the human mental process into Systems 1 and 2, which both include features that impact human decision-making processes (e.g., Evans, 2003; Kahneman, 2011; Stanovich and West, 2000). System 1 represents the unconscious mind; it is fast and emotional and is based on previous experiences (e.g., intuitions and tactical knowledge). Most decisions are based on System 1 because it saves energy, not demanding extensive mental effort. This easy way of making decisions is prone to error (Kahneman, 2011). To prevent possible mistakes, System 2 can be activated, as it is more deliberate and logical. However, it also demands more energy (Luokkala and Virrantaus, 2014). System 2 monitors System 1 and might prevent poor decisions made based on biases,

enables a comparison of different alternatives, and adapts the decisions to specific situations. Experts are basically able to identify critical information faster than others. However, their brain tries to reduce the use of System 2, such as for all humans; they want to select the first option that comes to their mind. Another important notion on System 2 is that human correction for biases actually tends to malfunction during stressful situations (Boin et al., 2017).

Intuition is a discussed element in decision-making theories, starting with Paul Meehl's *Clinical versus Statistical Prediction: A Theoretical Analysis and a Review of the Evidence* (1954, cited in Kahnemann, 2011), which reviewed a series of studies that had analyzed intuition versus statistic predictions. His results, among many other studies investigating this phenomenon after the publication of the book, revealed that 60% of the studies had proven statistical algorithms (e.g., the technologization of procedures) to be more accurate than intuition/expert judgment (Kahnemann, 2011). One of the explanations for the statistical superiority is that humans tend to think untraditionally and are too complex in their combination of information. Even when evaluating the same data twice, they provide different answers (Kahnemann, 2011). This view on intuitions and expertise is that intuitive judgment is flawed and forms the "heuristics and biases" view (Kahnemann and Klein, 2009). Biases are grounded in heuristics that come from personal experiences, and as the heuristics are automatic procedures, humans often find an incomplete and thus potentially damaging solution to urgent and difficult problems (Luokkala and Virrantaus, 2014). Human judicial evaluative functions regarding risk assessment in time-critical environments are increasingly being supplemented by algorithmic AI tools that provide more accurate objective assessments. However, concerns about potentially in-built statistical biases and the weakening of human judgment have been raised (McKay, 2020). McKay (2020) investigated decision-making delegated to a predictive tool in the criminal jurisdiction and concluded that "while algorithmic instruments may be useful and complementary predictive tools, they have no role as a sole or final arbiter" (p. 35) because an imperfect algorithm is hard to verify.

Intuition tends to be associated with mysticism and magic, and several scientists have investigated the phenomenon (e.g., Simon, 1969, cited in Frantz, 2003). While being a part of the development of computers ("thinking machines"),

Herbert Simon understood that human intuition is subconscious pattern recognition (Simon and Gilmartin, 1973). Simon showed that "intuition is not a process that operates independently of analysis; rather the two processes are essential complementary components of effective decision-making systems" (Simon and Gilmartin, 1973, p. 33).

4.2.2 The NDM view

Experienced stakeholders from different emergency organizations make decisions in highly complex environments, where the time pressure does not allow them to generate and evaluate a large set of options (activating System 2) that might provide the right decision. In 1985, Klein and Associates investigated this phenomenon for the US Army Research Institute. They studied the decision-making process of foreground commanders and found that such experts rarely had to evaluate different options when making decisions. Actually, an expert does not consider several options at all; they mostly generate a single option (Klein and Crandall, 1996). This is one of the elements that characterize NDM, which is a theory on how people make decisions in a real-world context that is familiar and meaningful to them (Lipshitz et al., 2001). People make decisions based on prior experience by rapidly categorizing different situations (Klein, 2008), which can be compared to pattern-matching mechanisms and mental models. To explain how this phenomenon happens, several theories based on NDM have been developed (Lipshitz, 1993), such as Hammond's cognitive continuum theory (Hammond et al., 1987) and Rasmussen's (1983) model of cognitive control. Another theory among the NDM doctrine is the RPD model. The RPD model has received significant attention in NDM theory and explains how experts use their experience in the form of a repertoire of patterns (Klein et al., 1986) and make successful decisions extremely rapidly because they do not have to compare several options. Another component that characterizes the RPD model is the use of mental simulation, where the actors imagine how the action in the specific situation would play out. If the option is considered to work, they can act; if it does not, they can adjust the option until it seems right. This is the reason why Klein (2008) calls the RPD model "a blend of intuition and analysis" (p. 458), as the model's pattern matching is the intuitive component (System 1), and the mental stimulation is the conscious, deliberate, and analytical component (System 2). One important notion is that the pattern-matching mechanism and

chosen course of action are not solely retrieved from memory. The actor must, in most situations, construct a unique action customized to the specific situation.

The RPD model has three application versions (figure 5), where each variant suits a situation having a particular level of cognitive complexity (Klein, 1993). First, the easiest application phase is used when a situation is recognized and the stakeholder's obvious reaction is implemented (A. Simple Match). Second, if the recognition is not as obvious, the stakeholder applies a more complex phase by using imagination to uncover problems before carrying it out (B. Developing a Course of Action). Third, the most complex phase of RPD involves the stakeholder evaluating different options, revealing flaws requiring modification. Alternatively, the option is assessed to be inadequate, and the stakeholder chooses the next most typical reaction (C. Complex RPD Strategy).

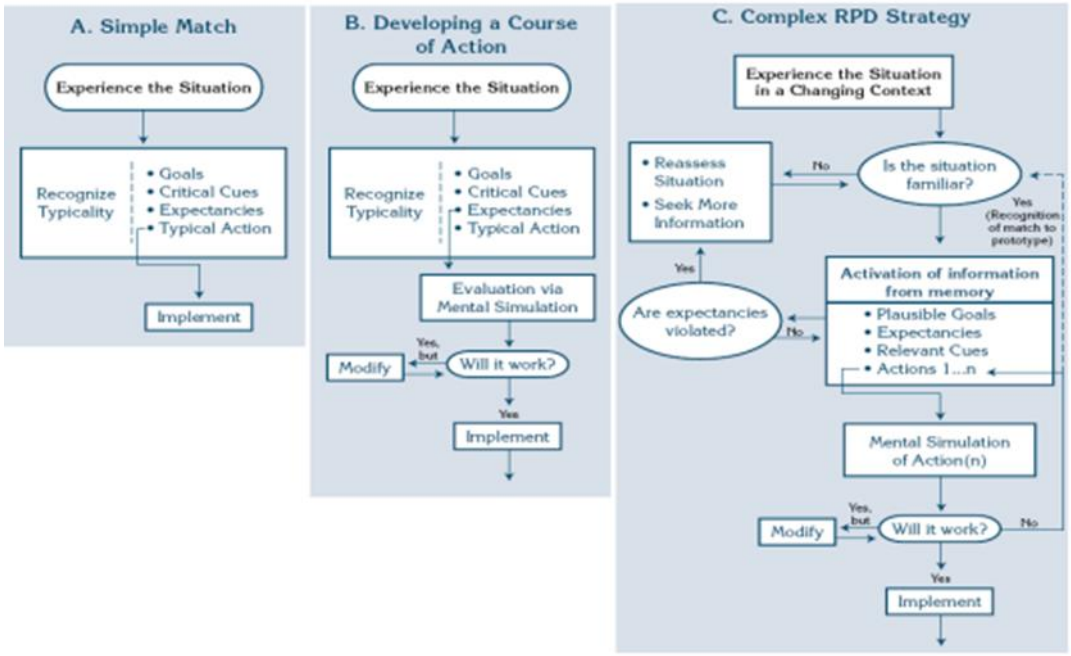

Figure 5: The three different versions of the recognition-primed decision model (Kankanamge, 2010, p. 21)

NDM and more classic decision-making theories, such as HB, represent contrasting viewpoints that influence the discussion on how to develop procedures and facilitate decision-making processes because the stakeholders are working with different perspectives (for example, at different C2S).

NDM highlights the experts' intuition and claims that they can successfully make decisions based on intuition (e.g., pattern-matching mechanisms and mental models), while the HB approach favors algorithms. This contradiction generated a discussion between two of the pioneers of each field. First, David Kahnemann (e.g., *Thinking, Fast and Slow* [2011]) emphasizes the more classic DM theory by favoring algorithmic DM as the most successful way of making a decision. Second, Gary Klein (e.g., *Sources of Power* [1998]) emphasizes NDM and the RPD model and shows skepticism toward using rigid mathematical algorithms instead of human judgment. Both Klein and Kahnemann agreed on intuition as a skill and on how to access such skills – namely, through experiences/emotional learning (fast) and expertise (more time consuming because it does not consist of a single skill but a large collection of several skills). However, their published works seem to disagree on the validity of the judgment of an expert who claims to have good intuition. Klein's attitude toward this was characterized by trust and respect, while Kahnemann's attitude was characterized by skepticism. In their common paper "Conditions for Intuitive Expertise: A Failure to Disagree" (Kahnemann and Klein, 2009), they compared their views on the issues of intuition and expertise and concluded that they had different experts in mind. For example, in environments involving the relationships between objectively identifiable cues and later events, or between cues and the outcomes of possible actions (which are somewhat regular), expert judgment is more likely to succeed (unlike, for example, a stockbroker environment, which has weak regularity) (Kahnemann and Klein, 2009). This notion is important when discussing decision-making procedures in different EM structures because the procedures seem to have to be adapted to the different C2S and the level of experience of the stakeholders.

4.3 Sensemaking

One of the core challenges in EM is the sensemaking of unfolding situations from their roots to their "hot" phase and the aftermath (Boin et al., 2017). Sensemaking is what actors do so they can decide how to act in different situations they encounter (Weik, 1995). Stakeholders in EMOs must make several decisions during the management of different crises; thus, sensemaking is an important factor that procedures and other structures must support. For example, procedures can guide actors by categorizing cues and measures.

According to Weik (1993, p. 635), “The basic idea of sensemaking is that reality is an ongoing accomplishment that emerges from efforts to create order and make retrospective sense of what occurs.” It is a process that addresses questions such as *What is going on? Why? What may happen next? What can be done about it?* and, retrospectively, *Why were these actions taken*? By answering these questions, the sensemaking process has an important impact on outcomes (Weick, 1993).

When discussing the research on sensemaking, there are two different meanings: (1) the cognitivist version where *sensemaking leads to the formation of shared mental cause maps,* and (2) the constructivist version where *sensemaking leads to actionable intersubjectivity constructed through language* (Sandberg and Tsoukas, 2015, p. 8). The latter meaning is drawing on a more phenomenologically oriented enactive cognitive science which suits this dissertation project`s approach. However, the development of mental models is an important theoretical concept in this project and the sensemaking perspective is therefore based on both the cognitivist and constructivist versions. Both the first and the second meaning of sensemaking have roots in Weick`s (1993) work.

In time-critical operations, the RPD model can explain how stakeholders make decisions during the sensemaking process, as sensemaking is how the actor understands the information that creates the ecological change in the environment. However, since the RPD model explains decision-making as an isolated element in complex environments where the actor does not have the time to evaluate different options, the sensemaking process can explain how they assess the situation itself. Both the RPD model and the SA model have the perceptual learning aspect, whereas recognition is explained by experience (Roberts, 2018). The SA model explains how the stakeholder is perceiving information in the current situation and the future, and how they make decisions (Endsley, 1995). However, the SA model does not include the development resulting from experience between the current situation and future practice as Weick’s sensemaking does. While the sensemaking process aims to describe how stakeholders are making sense throughout the whole situation from end to end, the RPD model and the SA model explain what is going on in a specific event without taking the learning output into account.

Since organizations in the three-tiered C2S are different in many aspects (see section 2.2 and Article #6), the sensemaking process is also somewhat contrasting. While Weick's sensemaking process originates from James's (1907) pragmatism – that is, to the selectivity and the goal-directedness of human consciousness (cited in Jensen, 2010) – the Military Command and Control research community (Leedom, 2001) sees sensemaking as a process where stakeholders' understanding is mechanisms applied to awareness of the elements (Level 1 SA) in a specific situation. This means that sensemaking is "situational awareness" plus "understanding" (Jensen, 2010).

As mentioned in the previous section, the sensemaking process also aims to describe stakeholders' active seeking of controlling their environment as an end-to-end process that includes finding a way to accomplish a mission. Individual sensemaking can then be seen as an expansion of SA, as Albert and Hayes (2007) write: "Sensemaking spans a set of activities that begins with developing situational awareness and ends with preparation for action" (p. 34). These actions are guided by retrospective sensemaking which focuses on the stakeholders` background, experience, and knowledge as a whole. However, as important as individual sensemaking is, collective sensemaking becomes crucial when exploring multi-organizational EM. Collective sensemaking is how different stakeholders try to generate a common understanding for coordinated action in time-critical environments (Wolbers and Boersma, 2013). The linguistic factors are important in this sense, as sensemaking is performed by the negotiation between different stakeholders (Weick, 2009).

4.4 Normalization Process Theory (NPT)

To extract the benefits of new information sources, it is important to investigate how this affects existing workflows. Therefore, NPT (May, 2006, 2009) was chosen to provide a theoretical lens for part of the empirical data collection and to determine whether there are any workflow issues when implementing a novel system for information collection in a complex work environment. Further, in this context, NPT helps to identify the usefulness of IS and whether it justifies the effort of using it. NPT deals with "how and why things become, or don't become, routine and normal components of everyday work" (May and Finch, 2009, p. 535). It has been emphasized that there is a need for theory-driven

approaches to new practices that require complex changes in workflows (Grol et al., 2007) because a theory can provide universal and transferable explanations. NPT theory addresses this aspect in parts of this dissertation project.

The core of NPT is the work that individuals and teams do to facilitate an intervention to become a part of their everyday routine and thus be normalized. However, the normalization of systems implemented in different domains can also be denormalized (Murray et al., 2010) because they simply do not fit into the organization's workflows. NPT defines four domains (McEvoy et al., 2014): (1) *coherence***:** the sensemaking process stakeholders have to go through to favor or hinder the routine embedding of the IS use, (2) *cognitive participation***:** the process the stakeholders have to go through to engage in the new practice of using the IS, (3) *collective action***:** the work the stakeholders have to do to enact the new practice, (4) *reflexive monitoring:* the appraisal work that the stakeholders do to assess and understand the IS's effect and usefulness.

NPT has so far primarily been used in healthcare settings (Sutton et al., 2018); however, in this study, the organizations involved do not include the healthcare domain alone. NPT also takes individuals (both alone and as a team) into account. Thus, NPT helps to examine workflows, technology in everyday use, and practices of embedding (Pope et al., 2013) in a sociological matter.

5 Research approach

My personal motivation for this Ph.D. project came from my background as an emergency dispatcher in a medical CCC. The experience of having an insufficient understanding of the situation for making the right decision is familiar and less desired. I have several experiences and stories where the outcome of the crisis operations could have ended so much better if all involved stakeholders had a better understanding of the different perspectives of the situation. One particular experience comes to mind. A fisherman had fallen out of the boat on a fishing trip, and someone saw this from a distance and called the emergency services. Then several agencies were involved, such as the police service, sea rescue team, fire and rescue service, and me as a medical emergency dispatcher. We all did our work based on our agency-specific procedures, and none of us did something wrong. However, we did not manage to build a common situational understanding. We had different understandings of the incoming information, we had no technical systems for accessing a COP, and because of the heavy workload, we made decisions solely based on our agency-specific perspectives. The lack of a common situational understanding and several misunderstandings related to the victim's health status resulted in a delayed start of life-saving first aid. The fisherman died, but no individuals or agencies were to blame for it. Rather, it was a system error.

From such experiences, an urge to understand how stakeholders can build a better common understanding of the situation grew. However, it is important to acknowledge that my experiences do not serve as a foundation for any generalization. All humans, in general, tend to emphasize the experiences they have over knowledge created by research. Conversely, scientific knowledge is often built based on the aggregation of individuals' experiences. However, through the use of systematic methodology and theories, individuals' experiences can be transferred into scientific knowledge.

This chapter aims to illuminate the research process and outline the research approach and design. It starts by presenting the research perspective and why I chose the phenomenon-driven approach. My onto-epistemological position will be introduced to explain the basic framework for the analysis of the data. This is followed by the data collection methods and analytical processes. Finally, I

conclude the chapter with considerations on the validity of the results and ethical considerations.

5.1 Research perspective

To answer the RQs, I had to reflect on my philosophical grounding. The concepts of ontology and epistemology are important because they say something about how I see the world and how I study the phenomena. This is an important component for researchers to understand and be clear about in their dissemination of research (Walsham, 1995b), and these concepts should be an initial focus (Hassan et al., 2018).

The research objective in this dissertation project involves, among other elements, the study of human behavior in the social world when in time-critical and challenging environments, and I was seeking answers to why stakeholders act as they do. Ontology is the philosophical study of the nature of being (Delanty and Strydom, 2003). My ontological assumption is that the form and nature of reality is a social construction (Berger and Luckmann, 1966), the people in the world are being defined by the world, and the social world is defined by the people in it. Constructivists "assert that social phenomena and their meanings are continually being accomplished by social actors" (Bryman, 2012, p. 710). The ontological perspective of the dissertation project is thus constructivism.

Epistemology is the theory of knowledge and explains how a theory can be formulated. Epistemology concerns "philosophy that investigates the possibility, limits, origin, structure, methods, and validity (or truth) of knowledge" (Delanty and Strydom, 2003, p. 5). The most common traditions practiced for distinguishing epistemological foundations in social science are positivism, interpretivism, and critical research (Delanty and Strydom, 2003). The positivist view explains the world as predefined, and the knowledge of reality can be explained through causality and reduction. It is important to separate the subjective from the objective. Further, the positivist view aims to test theories and make predictions. Interpretivism includes a relativistic view of the world. The world is not predefined; it is a result of several conditions that change over

time. Critical research suggests that social reality is constructed by humans over time and aims to improve lives (Myers, 1997).

The early and still most common tradition in IS has been in a positivistic direction (Hassan et al., 2018). Articles based on interpretivism have, however, increased since the early 2000s. Interpretivism appears to be the opposite of positivism, where knowledge rises in the subjective experiences in the social world. Both these approaches have their strengths: the positivistic view can offer statistical generalization, while interpretivism can provide analytic generalization and in-depth understanding (Chalmers, 2013). Interpretivism claims that reality is constructed from human thought and that reality cannot exist outside human recognition (Bhaskar, 2013).

Consistent with my ontological view, the epistemological perspective in this project is interpretivism, and the contribution to knowledge is understanding through cognitive processes and a hermeneutic approach. Interpretive reasoning has become an entrenched part of sensemaking in IS research (Walsham, 2006), and it argues that in the orientation toward reality as a social construction (e.g., shared meanings and language) by human actors, one must combine explanation and understanding (Klein and Myers, 1999). For example, when a researcher investigates a phenomenon, the researcher and the informant interpret the situation studied (Nandhakumar and Jones, 1997; Weber, 2004) to reach an in-depth understanding (Chen and Hirschheim, 2004). Therefore, for generating interpretive knowledge and gaining a deeper structure of a phenomenon, field studies have been suggested to be the most suitable research strategy (Orlikowski and Baroudi, 1991). Unlike the positivistic view, interpretivism aims to provide analytic generalizability from the phenomenon studied (Walsham, 1995b).

Interpretive research has become an important strand in research in the IS field (Walsham, 1995a) and can help researchers to understand human thoughts and actions in the context of both organizations and social life (Klein and Myers, 1999). In this dissertation project, it was necessary to produce deep insights into the use of IS for supporting human processes such as making decisions and developing common situational understanding. This was done by investigating the complexity of human sensemaking in the contexts where the phenomena occur, and the phenomena were understood through the meanings that the

stakeholders assign to them (Gioia and Chittipeddi, 1991; Orlikowski and Baroudi, 1991).

The philosophical basis for interpretivism is phenomenology and hermeneutics (Myers, 1997). Phenomenology was grounded by the philosopher Edmund Husserl around 1900 and further developed as an existential philosophy by Martin Heidegger; it aims to understand human natural experiences concerning a phenomenon. Heidegger suggests that the study of human experiences is through varied languages and discourses (Delanty and Strydom, 2003). In qualitative research, phenomenology seeks to understand the informants' perspectives and describes reality as the informants' perceptions of it (Kvale and Brinkman, 2009). Van der Zalm and Bergum (2000) state, "Phenomenology contributes to empirical, moral, aesthetic, personal, and socio-political knowledge development" (p. 211). Hermeneutics concerns the interpretations of human experiences and seeks to achieve an understanding of the human world (Thagaard, 2009). The context is essential here for understanding the phenomena being investigated, as the phenomena can only be understood in the context in which they occur (Johannessen et al., 2007). The interpretation is an interaction between the researcher and the interview data because the researcher's understanding affects the interpretation of the data (Thaagard, 2009).

Hermeneutic phenomenology has both descriptive and interpretive elements (Heidegger, 1962, cited in Lopez and Willis, 2004). The objective is the investigation and description of a phenomenon as the experience of human lives by using phenomenological reflection (van Manen, 1983). Thus, it does not prescribe clinical procedures for action; however, hermeneutic phenomenology contributes to "a thoughtful reflective attentive practice" (Van der Zalm and Bergum, 2000, p. 2), as it exposes the meanings of human experience.

The key objective in this dissertation is to advance knowledge of how to develop a common situational understanding in EM that relates to multi-organizational collaboration, IS, and human interactions. This requires a deep understanding of the context and human relations. Constructivism is the ontological grounding of this dissertation project, as it describes how humans construct the social reality in which they participate. A deeper understanding of the phenomenon investigated was approached by gaining multiple perspectives, and I as the researcher aimed

to make appropriate connections (Charmaz, 2006). I believe that lived experiences and in-depth knowledge of the investigated area obtained from the stakeholders were necessary for understanding and contributing to the investigated part of the EM domain. Also, the stakeholders have different experiences and professional backgrounds and use different terms related to emergency operations. Based on this, the epistemological assumption in this project was chosen to be interpretivism. Phenomenology and hermeneutics are the philosophical bases, given the importance of the stakeholders' perspectives and in-depth knowledge related to the research objective. Klein and Myers's (1999) seven principles for evaluating interpretive IS field research were used for validation. Table 6 summarizes the elements comprising the research perspective of this dissertation project.

Table 6: Overview of philosophical grounding

Elements of the research perspective	**Stance chosen in this research**
Ontology	Constructivism
Epistemology	Interpretivism
Philosophical base	Phenomenology and hermeneutics
Role of the researcher	Outside observer/in part also involved observer
Role of theory	An initial guide for data collection and analysis
Research strategy	Interpretive field study

5.1.1 The role of the researcher

Gaining access to stakeholders' interpretations and perspectives is a challenging task (Walsham, 1995b), and I had to reflect on my role in this process. Walsham (1995b) identifies two different roles of being a researcher: the outside observer and the involved researcher. The outside observer is not connected to any of the study objects (people, groups, or organizations) during the study. This allows the researcher to see things from new perspectives and conceptualize people's interpretations more freely. The involved researcher has direct and personal access to the research setting.

I was generally an outside observer; based on my experiences from a part of the EM operations, I had an understanding of the context from the inside (Walsham, 1995b). In my former work, I often collaborated with other organizations, which provided me with in-depth knowledge of their perspectives related to their work. I also understood their terminology and professional language. Hence, I experienced that the stakeholders viewed me in a positive light because they might have felt that the research aimed for their benefit rather than solely for the sake of academic research and pure theoretical perspectives. Some of my informants were also my previous colleagues. In this sense, my role was more similar to that of an involved researcher. During the whole project, I had to be aware of the possibility of starting to identify myself with the stakeholders in the field and thus lose an objective perspective of and critical attitude toward the situation (Walsham, 2006). For example, when I was an observer in the health CCC during one of the exercises (related to Article #1), I had to make clear to the stakeholders what kind of role I had in that scenario (an objective observer). Still, I had the advantage of knowing the context, background, and professional characteristics of the different stakeholders, which were important considerations during the data analysis.

I placed myself both as an outside observer and, in part, as an inside observer in this project. I understood the research context quite well based on my professional background; however, I was unfamiliar with the overall perspectives and work processes in the different organizations performed by the various stakeholders at the different C2S. In addition, I was unable to observe the day-to-day working processes in the various organizations by having direct and personal access.

5.1.2 The role of theory

The theories presented in Chapter 4 were used as an initial guide, although not restrictively, for designing the data collection tools in this project (Walsham, 1995b). The theory also had a role in the analytical process, where both different SA levels and different theoretical views on decision-making were important for interpreting the data collected. NPT was an important guide for both data collection and data analysis in Article #5.

I was aware of the danger of using the theories in an overly rigid way and decreasing my openness to any novel aspects (Walsham, 1995b). I was thus open to novel insights, and rather than only systematizing the data according to the theory, I developed new themes from the data that emerged from the interpretive research approach. Interpretivism considers social inquiry as a way to enhance the researcher's understanding of the social world, not to produce causal explanations of social phenomena (Walsham, 2006).

During the response phase in EM explicit awareness of the situation by all involved stakeholders can be important, however, all cannot have access to or hold the capability to process all information. This constitutes the need for the stakeholders to communicate based on their SA and collaborate for both individual SA and common situational understanding. I argue that SA both is an individual state and a consequence of communication and collaboration activities. Both are based on the stakeholders' perspectives, experiences, and negotiations between each other concerning the specific context they are facing. The focus of this dissertation project is research on human performance in a socio-technical system and thus aims to describe and understand both the individual and collaborative aspects of such systems. The SA levels are not used for cognitive task analysis which is typically a positivistic approach, but rather the model`s three theoretical constructs (perception, comprehension, and projection) are used for understanding and discussing what information needs to be shared, how, and at what time for the stakeholders to develop SA. Further, SA constitutes several human cognitive aspects such as mental models – which again lead to decision making and actions. This is based on the interaction between the involved stakeholders and their experiences of the world environment. Conflicting individual SA and loss of common situational understanding can be restored with the use and help of IS for supporting SA, interactions, and decision making.

5.2 Research design

The logical sequence connecting the empirical data to the RQs and conclusions is described as the study's research design (Yin, 2017). The initial question the researcher must ask themselves is what kind of evidence is needed for answering

the RQs sufficiently. The research design is a kind of framework that includes chosen methods and techniques, justifies the selection of what data are relevant and necessary to collect, and describes how to analyze the data (Philliber et al., 1980).

Qualitative research can be described as a naturalistic interpretive science with multiple methods in focus (Mertens, 1998), such as interviews, observations, textual analysis, and case studies that provide knowledge and insights into organizational practices, cultural aspects, and human interactions (De Villiers, 2005). Often, reported studies do not distinguish between "interpretive" and "qualitative" research (Munkvold and Bygstad, 2016), but Klein and Myers (1999) emphasize that interpretive is not a synonym for qualitative since qualitative research may or may not be interpretive. This is based on the researcher's philosophical assumptions.

The dissertation project's main approach is an inductive qualitative research design. For the data collection in Article #5, a hybrid approach (Fereday and Muir-Cochrane, 2006) was used. The semi-structured interview guide (Appendix C) had an a priori template of codes consisting of NPT domains (coherence, cognitive participation, collective action, reflexive monitoring) which are consistent with a deductive approach. The NPT domains were applied for organizing the data for later interpretations. However, themes from the data using a data-driven inductive coding complemented the thematic analysis allowing the tenets of social phenomenology to be integrated, which constitutes a hybrid approach.

Qualitative data collection and analysis produce findings that include values and human experiences, and the researcher functions as an instrument in the interpretation of the data (Leedom, 2001). Articles #1, #2, #3, #4 and #6 all used an inductive approach. The SA model and the RPD model were considered when forming the basis for the initial data collections (see table 7 for examples). Nevertheless, this did not imply restrictions in the collection of data, as the observations, audio logs, surveys, and qualitative interviews were open for additional information and reflections. The inductive strategy is based on the researcher's open mind when collecting relevant data. Data categorization and

systematization are done after the data collection, and by this open approach, the theory is generated inductively from the analysis of contextual data.

Table 7: Examples of how theory has been used in the data collection instruments

Theoretical models	**Question in the interview guide**
SA model	What kind of knowledge does this information provide you / what does it tell you? Can you give examples?
SA model	What can you predict – i.e. what consequences can you understand from this information?
RPD model	What decisions do (did) you have to make in [such] processes?
RPD model	What influences your decisions?
RPD model	How do you use procedures in such processes, and how are the procedures structured?

Since its early stages, this project has aimed to understand the structures for the development of common situational understanding in the EM of complex emergencies. As seen in figure 6, data was collected in 7 different clusters and resulted in six scientific articles and one article in a stakeholder magazine. The clusters comprise the collection of data related to specific purposes. For example, during the development of Article # 6, I used data from cluster 5 (the Mandal exercise), however, I needed additional data for answering the research question and therefore I chose to conduct several qualitative interviews and a survey. The clusters thus represent data collection aiming for a specific purpose and within a limited time perspective. Table 9 shows more specifically which informants are included in the data collection for the various articles, which year this was done, and which SQ it is related to.

Cluster 1 provided me with a quite unique set of data (see section 5.3.2 audio log analysis) that revealed the actual message exchange combined with the event timeline which showed the "live-image" of the communication among the collaborating stakeholders during the exercise. The contents in the audio logs provided preliminary ideas in terms of foci for narrowing down the further investigations, supplementing those that I had identified in the project proposal. An example was the need for identifying common information requirements between the different stakeholders involved in the EM of complex events.

The next step was to carry out data collection in clusters 2 and 3 for further investigation of the working processes and information requirements among the stakeholders. In terms of the findings, which will be addressed in more detail in Chapters 6 and 7, the observations from the audio logs and individual interviews conducted in cluster 3 provided evidence for the importance of the actors‘ assumptions on the concepts of COP and common situational understanding and the need for a clearer distinction between these concepts when it comes to practice. The data collection in cluster 4 was conducted for supplementing the audio logs and interviews (from cluster 3).

Two implications for further progression emerged from the results so far in the project: Firstly, how the NPSN successfully can be used for the negotiation of information for developing common situational understanding, and, secondly, to explore the stakeholders‘ views on how to successfully implement IS for data collection into their working environment. Data from the interviews (C, D) in cluster 5 provided stakeholders` perspectives on how to use NPSN successfully, and this was supplemented with additional data collection (in cluster 7). For the investigation of the second implication, data collection shown in cluster 6 was conducted.

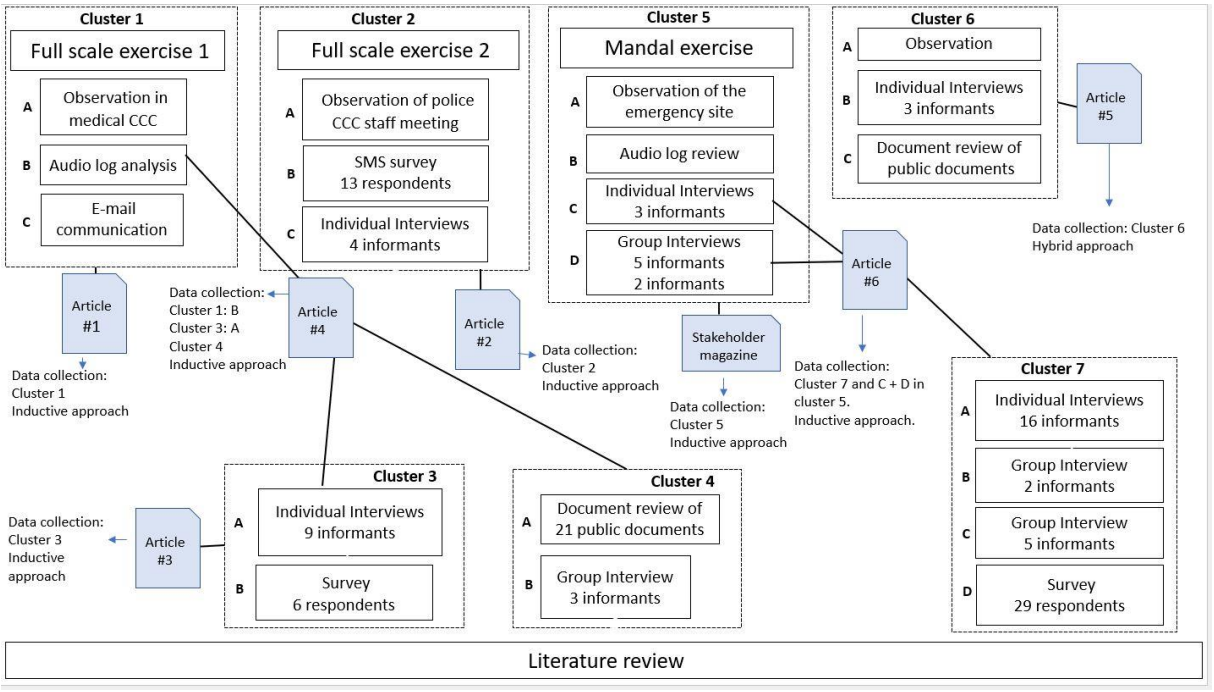

Figure 6: Research design

5.3 Research activities

This dissertation project aims to investigate a variety of contextual factors in the EM domain. By using multiple qualitative methods (table 8), findings from each method provided specific insights and understanding for the articles developed. The qualitative methods employed include analysis of audio logs, interviews, surveys, document review, and observations, which provided a multi-faceted examination of issues that could not be gained from any single method (Johnson et al., 2017). The methods will be described in this section.

Table 8: Multiple methods

Method	A#1	A#2	A#3	A#4	A#5	A#6	Notes
Audio log analysis	X			X			5, 24 hours
Qualitative interviews		X	X	X	X	X	53 informants
Surveys		X	X			X	38 respondents
Document review				X		X	21 documents
Observation of exercises	X	X			X		3 + 1 (section 6.8)

The collection of data in this project was a continuous process, where the data collection, memo writing, and analysis process led to more questions that required additional data collection (Corbin and Strauss, 2008). Table 9 presents an overview of the data collected in the different phases of the Ph.D. project.

Table 9: Overview of the timeline/phases of data collection

Period	Method	Description	Data used in the following publications
2018	Observation in a CCC, audio logs, email communication with stakeholders related to the results	Full-scale exercise 1. We analyzed the audio logs and posed questions to the involved organizers and participants after the exercise both for collecting their opinions and clarifying uncertainties in the results.	**Article #1**: Using audio logs for analyzing the development of a common operational picture in multi-agency emergency response

		Related to SQ1	**Article #4**: From common operational picture to common situational understanding: An analysis based on practitioner perspectives
2019	4 individual qualitative interviews Observation of police CCC staff meetings SMS survey with involved stakeholders	Full-scale exercise 2. I conducted individual interviews with stakeholders participating in the exercise as a part of the INSITU project. Related to SQ1	**Article #2:** SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise
	9 individual qualitative interviews Survey of 6 key stakeholders in EMOs	Individual interviews with first responders and municipalities, and survey of stakeholders beyond the first responders and municipalities (supportive organizations). Related to SQ2	**Article #3:** Identifying information requirements for improving the common operational picture in multi-agency operations
2020	3 individual interviews, 1 group interview with 2 informants, 1 group interview with 5 informants Audio logs Observation A group interview with	A small-scale exercise (see section 5.8). I observed the exercise, interviewed the involved stakeholders directly after the exercise, and received the audio logs (BAPS common call group for first responders). I also took the opportunity to ask the participants questions from the interview guide regarding NPSN. Related to SQ1 and SQ3 Individual interviews: police officers (3 informants) Group interviews: Fire crew (5 informants) and ambulance crew (2 informants). This division was related to the informants' wishes. I had to learn more about the structures/processes behind the use	Kristine Steen-Tveit (2021). The simplest is often the best. *Stakeholder magazine/Police Forum* **Article #6**: Using a public safety radio network for information negotiation between the three-tiered command and control structure **Article #4:** From common operational picture to

	3 managers from the NPSN, 1 individual interview with a GIS vendor Document review	and development of both the NPSN and a GIS used by the first responders. 21 public documents were reviewed to identify current practices and evaluations of real events.	common situational understanding: An analysis based on practitioner perspectives.
	23 informants: 16 individual qualitative interviews, 1 group interview with 5 informants, and 1 group interview with 2 informants	These interviews were conducted both face to face and online. The group interviews included incident commanders from police services and an ambulance crew. I chose to perform these interviews as group interviews because I had a group interview with a fire crew at earlier stages. These stakeholders often make decisions in collaboration by negotiating with each other. The individual interviews included stakeholders from organizations across the three-tiered C2S. Related to SQ3 and SQ4	**Article #5**: Using live video for communication between lay bystanders and emergency dispatchers in command and control centers. **Article #6**: Using a public safety radio network for information negotiation between the three-tiered command and control structure
2021	Survey with 29 respondents One group interview with 3 informants	Being a part of the INSITU project team (https://insitu.uia.no/), I was able to manage the verbal communication part of the INSITU exercise. This included both developing learning material and conducting the evaluation of this through a survey (24 respondents). I administered a survey for evaluating verbal communication during the exercise (29 respondents). I also conducted a group interview with three key participants one week after the exercise, focusing on the use of the NPSN and evaluation of the exercise. Related to SQ3 and SQ4	**Article #6:** Using a public safety radio network for information negotiation between the three-tiered command and control structure .

5.3.1 Selecting informants

There are limited references to several of the aspects of this dissertation project's RQs, such as the specific information requirements of multi-agency operations, user perspectives on the process of establishing common situational understanding, and the communication and interaction between stakeholders in the process of establishing a COP. The people working in the various EMOs are considered "knowledgeable agents" (Gioia et al., 2013). This term is used to address the unique insight of experts regarding their own working processes. These stakeholders functioned as informants because they are experts in their fields (Alvesson and Ashceaft, 2012) and provided valuable information addressing my research objectives.

The project's population is experienced stakeholders (i.e., experts) in the most important EMOs in Norway. However, some stakeholders were believed to be more able to provide relevant information for my research objective than others. For example, when investigating procedures for collaboration, the first responders are the experts on this because they have collaboration procedures as mandatory tools in their workflows. They also use, to a large extent, the NPSN for supporting this collaboration. Further, the first responder agencies have to collaborate on a daily basis. Nevertheless, their collaborative workflows are far from perfect, but they are the organizations that have come the farthest in this area. Other EMOs, such as the Civil Defence, the County Governor, municipalities, and NGOs, have no collaborating procedures in a similar structured and specific manner. Thus, I have a larger proportion of first responders as informants in this project. The additional organizations do not handle emergency operations nor collaborate to the same extent as the first responders; however, they have to collaborate on several occasions, such as during extreme weather events. These organizations have quite different approaches and IS for multi-organizational emergency operations, as is documented in Article #3 and Article #4.

Alvessond and Ashcraft (2012) suggest two guidelines for selecting informants: representativeness and quality. Representativeness includes "some breadth and variation among interviewees such that they allow coverage of the social category one seeks to explore" (Alvesson and Ashcraft, 2012, p. 247). In this

sense, I identified experts in the different organizations by, on some occasions, approaching the manager, presenting my research, and asking them if they could refer me to the best suitable person (e.g., stakeholders with long experience and/or extensive knowledge of the topics). Informants also provided me with names of persons who could provide valuable and rich information about my research topic, also called snowballing (Yin, 2013). Regarding quality, my informants were interested in the project topics, and many of them were a driving force for improvement in their respective organizations. They were all very enthusiastic and willing to share their knowledge.

Some of the interviews and the surveys were related to the full-scale exercises that I observed (section 5.3.5). On these occasions, the informants were participants in the exercises and were not sampled by me, which is an opportunistic sampling method (Onwuegbuzie, 2007). On one occasion, I was asked to participate by stakeholders and thus collect data as I wanted (see section 6.8).

5.3.2 Audio log analysis

I used audio logs as empirical data for two papers (Article #1 and Article #4) and as the basis for an interview guide (Article #6).

EMOs in Norway use the NPSN as a common platform for collaborative communication (See appendix F). The first responder agencies are the core users of the NPSN, and it is the main tool for verbal communication in their daily operations. The stakeholders use different channels, depending on their roles and information needs. The system allows users to communicate in call groups across agencies and geographical areas. For the data collection in this study, I used an inter-agency call group reserved only for first responders, named BAPS (fire-police-acute medicine cooperation).

Together with one of my supervisors, I got entry access to a fire CCC and was permitted to download the audio logs from the record system in use. The audio logs consisted of several tracks (i.e., the records of the communication were divided into several audio files). The tracks show the actual timeline with both silence and conversation. We downloaded all tracks related to the specific call

group and noted the time and duration of the tracks. The tracks together consisted of a total of 4.25 hours.

The tracks were transcribed in full to ensure the completeness of all messages. The dataset was also triangulated with the real-time textual logs documented by the police during the drill for validation of the content. For example, we could validate actions/responses by reading the police log and comparing this with the audio logs by the time stamps. However, the police log only functioned as a validation of the analyzed audio logs because we did not get permission to use such logs in any publication activity.

All event sequences were further reconstructed into a complete dataset and systematized with the following information:

- The origin of the information
- The recipient of the information
- The information content

The audio logs consist of communication between operative units and dispatchers from the police, fire, and health (ambulance) services. The inter-agency call group (BAPS) study functions as a collaboration channel for the first responders, and it is required for all actors in these agencies to continuously listen to this group. The communication mainly originates from different key stakeholders in the emergency response (table 10). Additionally, operative units from all mentioned services occasionally communicated in the inter-agency call group.

Table 10: Stakeholders involved in inter-organizational communication in BAPS audio logs

Emergency responder organization	Stakeholder
Police CCC	Emergency dispatcher
Fire CCC	Emergency dispatcher
Health CCC	Emergency dispatcher
Police	Incident commander at the coordination point
Health	Commander health/ambulance personnel
Fire and rescue services	Incident commander

After transcribing the audio logs, we organized the data on several Excel sheets, consisting of the following:

- Raw data
- Clean-up for visual analytics
- Documentations/clarifications
- Sorted categories
- Analysis

We discussed and classified the messages/raw data into a summary of messages (see table 11 for an example). Further, categorization by an inductive method was developed gradually through classification and reclassification based on the content of the messages until a stable, unique category framework emerged. In this process, we initially classified 22 categories and further narrowed them into 14 categories.

Table 11: Classification of the messages/raw data

	Using Timeline from BAPS3 files			
		Origin of message	Destination	Summary of message
l0:00		CCC 112	CCC 110	Have received a situation report in Sam Eyde
l0:03		CCC 110	CCC112	Yes
10:10		CCC 110	ILKO	Have you heard the situation
10:10		ILKO	CCC112	Received message
10:10		ILKO	CCC 112	Join tale gruppe BAPS3
10:10		ILKO	CCC 110	The bus hijacked in Sam Eyde
10:10		CCC 110	ILKO	Repetition of Event
10:10		ILKO	CCC112	Situation report from event location

We then sorted the messages and different stakeholders in a clean-up. We continually documented our clarifications and changes. Due to publication, the messages were also translated from Norwegian to English in this process. (See Appendix A and Article #1 for more details and data analyses.)

Audio logs were also used as the foundation for an interview guide (Appendix B). The interview guide was based on transcriptions of audio logs from a real forest fire in Southern Norway in May 2020. I got access to a fire CCC and was allowed to listen to a sequence consisting of the first hour of the incident, which included the alert phase and the beginning of the response phase. I transcribed the audio logs by hand first and then classified the content into descriptions of the content that conveyed the information sequences (see table 12). This whole process was done when I was physically in the CCC, as I

was not allowed to take any direct transcriptions out of the CCC. The rephrased communication sequences were sent to the involved organizations by email for consent and validation. These organizations included the police and fire CCCs, the Civil Defence, and the local energy company.

The communication was presented in the interview guide as a general summary (due to confidentiality) of the information exchange between different actors. For each information-sharing sequence (the emergency dispatcher talking to the caller/lay bystander or other stakeholders), different questions related to the information exchange and verbal communication using the NPSN were asked. Table 12 demonstrates the first information exchange sequence and related questions.

Table 12: Information exchange sequence and related questions

Information sequence	• *Location clarifications* • *Emergency event – fire* • *What is burning – bushes* • *Possible time since the origin* • *Fire development* • *Possibility of extinguishing the fire* • *Wind direction clarifications* • *Resources are sent* • *It is a school class in the area*
Questions regarding the information exchange	• Should your organization be notified at this stage based on this information? • What is the most important information for you to know (as a professional) at this stage of the incident (please prioritize this information from most important to least important)? • What decisions would you make at this stage? How? • What kind of actions would you perform (if relevant)? • What information would you (as a professional) ask for to increase your situational awareness and basis for decision-making? • What information must be negotiated?
Questions on verbal communication using a radio network (NPSN)	• What kind of challenges could have arisen if this had been communicated in a common call group at this stage? • What call group should/could have been used? • Who from your organization should be active in this call group? • How should an incident like this/this information ideally be communicated (e.g., the organization and prioritization of the message exchange in the common call group)?

5.3.3 Interviews

The qualitative interview is one of the most important tools for data collection in qualitative research (Myers and Newmann, 2007). In this dissertation project, qualitative interviews have been conducted in two ways; individual interviews and group interviews.

Interviews in interpretive research provide access to the informants' interpretations in the field (Walsham, 2006). When a conversation aims to collect relevant, exact, and reliable information, it is defined as a *professional conversation*. Its "purpose is to obtain descriptions of the life world of the interviewee with respect to interpreting the meaning of the described phenomena" (Kvale, 1996, pp. 5–6). The quality and reliability of the information received are dependent on trust between the participants and especially how the questions are asked (Rachlew et al., 2020). First, I experienced that my background as an emergency dispatcher provided trust between me and my informants. I believe that my EM experience, even if it was in a different area/setting than for most of the informants, helped to develop a sense of mutual understanding when discussing different challenges and opportunities, as well as language/jargon, tools, and routines, in the EM domain. Second, I used some principles from an interview technique based on international research that is originally a novel technique developed for the police; however, this method can be used in all conversations where interpersonal principles apply (Bruusgaard et al., 2013). The method is called KREATIV, and it includes the following principles: communication, rule of law, ethics and empathy, active awareness, trust through openness, information, and scientific grounding (Rachlew et al., 2020).

Rachlew et al. (2020) present six phases of an interview that use the KREATIV principles as a basis (table 13), and I applied specific elements when planning and conducting the qualitative interviews. The dynamics and flexibility in the phases are depicted graphically in figure 7.

Table 13: Rachlew et al.'s (2020) principles and how they are addressed in this Ph.D. project

Phase	Explanation	Elements used in this project
Planning	Provide/free up cognitive capacity and thus increase the opportunity to listen actively and facilitate communication. "Failing to plan – is planning to fail"	*Physical preparations* • Set up the time, place, and duration for the interview. Due to the unpredictable COVID-19 pandemic, some interviews had to be conducted digitally. • Develop an interview guide and consent form and send this to the informants in advance. • Find and check equipment, such as the recorder. • Be professionally dressed. • Plan for accuracy in terms of time spent. I never arrived late or spent more time than planned. *Mental preparations* • Since I have previous experience in the EM domain, it was especially important for me to have an open mind without prejudice and be curious and perform active listening. • I prepared for being both structured and flexible toward the informants' way of providing information. *Case/content preparation* • Develop an interview guide that facilitates relevant information collection and validate the guide with my supervisors.
Establish contact	A professional conversation might be characterized by asymmetrical communication, uncertainty, and pressure. How we as interviewers handle this can be crucial for the conversation's outcome.	*First impression* • The first impression is important for the outcome of the interview. We are judged by the first impression, and this can be crucial for the trust in you, your project, and the organization you represent. • I was always polite and responded quickly to inquiries. *Expectations* • I treated the conversation with the informant as a goal in itself, where the stakeholders got to talk about their experiences and not just as a means for my results. *Information* • I started the interviews by providing the informant with information about me, my project, the aim for the interview, and how I would treat

		the recording and data (metacommunication for developing a common understanding). • I opened for questions and small talk before I formally started the interview (i.e., used the interview guide and started the recorder).
Free explanations	Provide the informant an opportunity to give their views and versions. This is proven to provide the most valid information (minimal impact) and most details.	*Balance* • I focused on capturing answers based on the predefined interview guide and avoiding asking leading questions. • *Active listening and structure of the conversation* I nonverbally showed that I was attentive to the informant (e.g., eye contact), particulary tolerated silence, and never interrupted the informant. • I aimed to ask follow-up questions when it seemed like a natural part of the conversation. • I often repeated something informants said (mirroring) that was in my interest and asked them to elaborate. • I summed up some of the information in question form (allowing the informant to elaborate, agree, or correct eventual misunderstandings).
Focusing on specific elements	After the free explanation phase, interviewers can structure the conversation toward the elements of interest identified in the free explanation or the interview guide (moving from the general to the specific [Myers and Newmann, 2007]).	*Clarifying questions* • I asked closed questions after finishing a theme or the whole interview, both for validating that I have understood the informant right and covering other themes in my interest. • I tried to not only build the questions based on the informants' answers but also cover the different themes in my interview guide.
Ending the interview	A positive closure of the conversation is important because humans remember the highlights and end of events. A conversation that ends positively is	*Information* • I ended the interviews by asking if there was anything the informant wanted to add and presenting what would happen next with the data the informant had provided (metacommunication on the way forward, e.g., feedback, and validation).

	usually remembered as positive (Kahnemann, 2011).	
Evaluation	Learn from this interview and maybe adjust something the next time. Evaluate if the interview provided relevant and wanted information.	*Transcribing* • I transcribed the interviews as soon as possible to address quality assurance. • I adjusted the interview guide on some occasions by adding some questions (for example, I added the question "What information must be negotiated?" in the interview guide based on the audio logs [Appendix E] after the second round of interviews). *Sending quotes to informants* • I sent the quotes and context to the informants I quoted before submitting the papers.

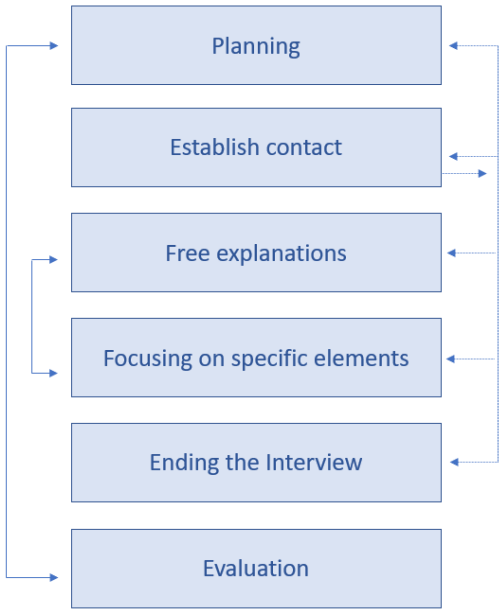

Figure 7: Phases, dynamics, and flexibility of the interviews (Rachlew et al., 2020, p. 104)

I used the KREATIV approach in combination with other principles and knowledge of qualitative interviews. For example, I used Schultze and Avital's (2011) guidelines for how to generate data and improve the formulation of theories through qualitative interviews: preparing for the interview with all my knowledge as a researcher, selecting informants, and designing and conducting the interviews. Myers and Newman (2007) discuss some pitfalls related to qualitative interviews – for example, that it is an artificial situation that can be

colored by a lack of trust and time pressure and that the researcher can interfere with people's behavior. I addressed these pitfalls by using the KREATIV approach. For example, I prepared for the interview by providing sufficient information and giving a positive first impression showing that I am competent and professional (establish trust), and I scheduled enough time for each interview (avoid time pressure).

The KREATIV approach (Bruusgaard et al., 2013; Rachlew et al., 2020) and Myers and Newman's (2007) suggested guidelines for the researcher are based more or less on the same principles. Rachlew et al.'s (2020) approach is outlined in the book *The Professional Conversation*, which provides a richer and more detailed picture of the approach. Further, it elaborates on the human factors underlying a professional conversation and emphasizes the "free explanation," which I personally have great belief in.

I developed semi-structured interview guides for the different rounds of interviews because this form of interviewing is based on a phenomenologically inspired perspective and aims to investigate the themes based on the informants' individual perspectives. Further, such a reflexive approach is consistent with my interpretive epistemology, where additional information beyond the interview guide can be relevant (Alvesson and Ashcraft, 2012).

The various interview guides used for conducting the interviews were developed based on the RQs in focus and previous research. The RQs were further broken down into lists of topics with related questions (and points for follow-up). The questions were developed to gain a better understanding of the context (briefly describe the organization, workflows, and current work) and informants' experiences in a way that acknowledged that there is no "one size fits all" by asking them to provide a personal narrative. The questions were also constructed in a way that would work for the method of analysis. The applied theoretical lenses (see chapter 4) also guided some of the design of the interview guides. SA model and NPT were especially important in the development of the interview guide for Articles #1 and #5, respectively. For example, the four domains of NPT served as important guidelines for the questions in the interview guide. Appendix C briefly shows the categories in the different interview guides developed for the articles included in this dissertation.

The guide for Article #5 was adapted for the different professional roles filled by the interviewees – meaning that the questions were phrased differently, depending on whether the person interviewed was a first responder, a stakeholder from an additional EMO, or a person involved in the scenario described in the interview guide (see Appendix B).

Semi-structured interviews are the most used interview technique in IS research (Myers and Newman, 2007). I conducted both individual and group interviews. The group interviews included stakeholders from the first responder agencies (see section 5.3.1). I chose to have some group interviews with these because they both make decisions and negotiate strategies as a group during their working day. Throughout the whole project period, I conducted 39 qualitative interviews with 53 informants altogether (table 14). Also, I aimed to interview stakeholders with varying roles within the organizations to represent different perspectives within the contexts (Myers and Newman, 2007). Two key stakeholders were interviewed twice.

Table 14: Overview of informants for qualitative interviews

Organizational unit	**Roles (number of informants)**
Health services	• CCC, head of section (1) • Incident commander (1) • CCC emergency dispatcher (2) • Paramedic/operative officers (3)
Fire and rescue services	• Incident commander (3) • CCC emergency dispatcher, shift leader (2) • CCC emergency dispatcher (4) • Firefighters (4) • Professional developer (1)
Police services	• CCC emergency dispatcher (8) • Incident commander (3) • Operative officer (1) • Head of section (1)
Red Cross	• Operative commander (1)
Civil Defence	• Head of section (1) • Operative commander (1)

Norwegian Directorate for Civil Protection	• Special advisor (1)
County Governor's office	• Preparedness advisor (2) • Head of section (1)
Municipality	• Emergency coordinator (4) • Head of preparedness section (2) • Operative nurse (1)
Energy company	• Preparedness coordinator (1)
System vendor	• System developer (1)
Norwegian Public Safety Network	• Manager (3)

The project was approved in advance by the Norwegian Centre for Research Data. I sent an information letter explaining the aim of the project and collected written informed consent from the informants before the interviews were conducted. For the Mandal exercise, I brought the consent letter at the exercise because I had no overview of who the participants were in advance. The interviews lasted from 44 to 75 minutes and were recorded. This applies to all interviews, except for the interviews with the managers from the NPSN in which I took notes. The interviews were carried out primarily through face-to-face meetings; however, due to the COVID-19 pandemic, some had to be conducted using technologies such as Microsoft Teams, telephone, or Skype.

5.3.4 Surveys

I used a survey as a qualitative research tool on two occasions in this project. The surveys mainly included a set of open-ended questions centered on a particular topic. The surveys invited the participants to provide their subjective experiences, practices, and positioning by answering with their own words and thus captured the sensemaking of the participants, which produced rich and complex data (Clarce and Braun, 2013). This data collection method can offer both researchers and participants numerous benefits, such as being less burdensome for the participants. For example, they can choose how much time they want to spend on the task, and it does not have to be at a particular time and location (Braun et al., 2021). The informants in this project have hectic workdays, and by using this method, I could collect data from people who are

usually difficult to reach. An example is the director from the Ministry of Justice and Public Security (table 14).

Survey 1: Information requirements

This survey, developed with SurveyXact, started with a question on what organization the respondent came from and further included four open-ended questions concerning information needs in extreme weather scenarios. The survey was sent to 10 stakeholders, and six respondents from different organizations answered the survey (table 15). The following organizations did not answer the survey: police services, Red Cross, the Norwegian Rescue Dogs, and DSB.

Table 15: Information requirement survey's respondents

Organizational unit	Role (number of respondents)
Fire and Rescue Services	Professional development (1)
Medical Services	CCC professional development (1)
Municipality	Head of preparedness section (1)
The Ministry of Justice and Public Security	Director (1)
The County Governor's office	Assistant director (1)
The Civil Defence	Head of district (1)

After stating which organization the participants represented, a brief description of a scenario was introduced (storm and flood). After this description, the following questions were posed:

- "What information needs are critical for your organization in this scenario?"
- "How can this information be verified?"
- "When handling such crisis events where there are victims, how do you understand the following terms, and when would you use them?"

Nine terms that defined an unconscious victim were then listed (Appendix D).

Survey 2: SMS survey

This survey was conducted during a one-day full-scale exercise in 2019. The scenario was an industrial fire that spread to the nearby forest and included a search for a missing person. The purpose of the exercise was to train the first

responder agencies and the municipal crisis management team on cooperation, coordination, and evacuation of inhabitants in the affected area. We used an SMS-based survey (SurveyXact) as the method for evaluating the stakeholders' SA during the exercise by sending a link to seven questions (table 16) to 16 key actors at two different stages of the exercise.

Two professionals (one paramedic and one CCC emergency dispatcher) who could not participate in the exercise functioned as pilots and received the SMS-based survey sometime before the exercise. They provided feedback that led to some updates. The questions were based on some of the important elements in achieving SA, such as receiving information (questions 1, 2, and 3), how to comprehend the information (question 4), prediction of future status (question 5), and knowledge about available resources (questions 6 and 7). Some of the questions were designed as multiple choice and with the possibility of including a free-text response to elaborate.

Table 16: Questions in the SMS-based survey

Number	Question
1	Have you been provided with sufficient information to form an understanding of the situation?
2	Who gave you the latest situation report?
3	How did you receive the information?
4	How do you understand the scope of the fire?
5	Which of the following critical community features do you believe is threatened?
6	Are all necessary resources for managing the situation present?
7	Do you know the location of the other resources?

The SMS was sent out to 16 participants (table 17). The respondents had decision-making authority and could provide valuable insights by answering such surveys during the operation. In addition, the SMS also was sent to one teacher and one student at a local media college acting as reporters to cover the emergency. This was considered an important aspect because their perspectives are the views that are conveyed to the public.

Table 17: SMS survey's respondents

Organizational unit	Role (number of respondents)
Fire and Rescue Services	• Incident commander (1) • CCC emergency dispatcher (1)
Medical Services	• Incident Commander (1) • CCC Emergency Dispatcher (2)
Police Services	• Incident commander (1) • Operative unit (1) • CCC emergency dispatcher (1)
Municipality	• Emergency coordinator (2) • Municipal chief executive (1)
Media College	• Journalist student (1) • Journalist teacher (1)
Red Cross	• Operative commander (1) • Operative unit (1)
County Governor's Office	• Counselor (1)

Of the 16 stakeholders that received the two rounds of the SMS survey, 13 participants answered the first round, and 9 participants answered the second. Nine of the stakeholders that received the survey were interviewed after the exercise. The interviewees were stakeholders from the following organizations: fire and rescue services (2 informants), ambulance (1 informant), police services (2 informants), municipality (3 informants), and the County Governor's office (1 informant). Of these, six had answered one or both SMS surveys. From these interviews, we learned there were several reasons the SMS was not answered by all – that is, interruptions when answering the survey, not having immediate access to their cellphone, and time pressure. The informants also expressed that such exercises tend to be very hectic. However, the informants expressed that they were mainly positive and that they had an understanding of the purpose. They also appreciated the goal of the survey because the evaluation of SA and COP is a difficult and important area for practice.

An SMS-based survey appears to be an effective and fruitful method for collecting real-time data, but there are some important learning points to consider in the future: First, open questions should be avoided. Second, the method should

be incorporated early in the exercise planning to prepare the participants and ensure their contribution. More details on the survey are presented in Article #2.

Survey 3: INSITU exercise survey

As a part of the INSITU project, I participated in a digital tabletop exercise. The scenario for the exercise included three simultaneous forest fires in Agder county in Southern Norway, creating the need for evacuation of inhabitants in the affected areas. The exercise allowed the participants to share a situation picture using a GIS module for forest fires as an example of more coordinated use of map support. In addition, the NPSN was used, with the possibility of using a common speech group for all participants involved.

In total, the exercise included 70 participants from 20 agencies and organizations, in addition to the project group from INSITU. The following actors were represented at the exercise:

- Fire department (ICs, operative units, and 110 CCC)
- Police services (ICs and CCC 112)
- The local hospital (CCC, 113)
- The Civil Defence, Homeland Security
- Arendal municipality, Kristiansand municipality, Kvinesdal municipality
- The state administrator in Agder (the County Governor’s office)
- DSB
- The Crisis Support Unit at the Ministry of Justice and Public Security
- Agder Energi
- Bane NOR (railway)
- The Norwegian Mapping Authority
- The Norwegian Public Roads Administration
- Telenor (telecommunications company)

A survey consisting of 28 questions regarding the use of the NPSN was sent out to all participants directly after the exercise. A total of 29 participants had used the NPSN and answered the survey.

5.3.5 Observation

I observed two full-scale regional exercises (FSREs) and one smaller exercise. I participated in the planning, observation, and evaluation of one tabletop exercise. The aim was to identify stakeholders' tools and workflows and obtain a sense of how the different organizations develop SA and a common situational understanding. Notes were taken during the observations. Table 18 presents the exercises observed.

Table 18: Observed exercises

Exercise, year	Observation site	Short scenario description
Full-scale regional exercise, 2018	Inside a health CCC, I sat by the emergency dispatcher; observed the use of the GIS, the operative IS for agency-specific tasks; and listened to communication with other stakeholders (both internally and externally).	Multiple manmade incidents/acts of terror. An attack on a bus with 20 student passengers, a traffic accident with injured people, and a large crowd attack during a music festival.
Full-scale regional exercise, 2019	Inside a police CCC/staff meetings, I observed how the different functions in the police work for providing staff with updates for developing SA and planning measures.	A forest fire developing at great speed. A manager of a kindergarten reports they have a department on a forest trip. She is not able to get in contact with the pedagogical leader in the group. An industry with propane tanks is threatened.
Small-scale local exercise with first responder agencies, 2020	On the emergency site, I could observe the whole operation and take pictures.	An abandoned bicycle was observed at a bridge, resulting in a search and rescue operation and two people found in the water (possible drowning).
Forest fire scenario (tabletop exercise), 2021	In the CIEMlab, I listened to the radio communication and watched the common GIS in use.	Three simultaneous forest fires in the Agder county in Southern Norway, threatening critical infrastructure.

5.4 Analysis

I had reflected on the data analysis process before I conducted the interviews, and the interview guide reflected the research objective and aim of the project. My data collection process had an explorative purpose. It is important to remember there is no one general or standard method for discovering significant opinions and deeper implications of what is said in an interview. The desire for a clear method can, however, emphasize techniques and reliability rather than knowledge and validity (Kvale and Brinkmann, 2009). Analyzing data in a qualitative research design involves making sense of the data (Creswell, 2009) and identifying patterns of meanings (Clarke and Brown, 2013) and takes place between the original narrative and the final story that I, as a researcher, tell the world.

Qualitative interviews were the main source for data analysis in this project; however, audio logs, surveys, and field notes from observations were also important sources. I conducted memo writing during the data collection and further into the coding processes. This was done because I needed to document my sensemaking of the data acquired. Appropriate sensemaking is a criterion for good research work (Weick, 1979). I took notes/wrote memos during and after the interviews. The notes were taken by hand, and I had them available while analyzing the interviews. All interviews were recorded, transcribed in full, translated the results from Norwegian into English, coded, and analyzed in NVivo. The data collection clusters (figure 6) were analyzed separately related to the corresponding Article, however, when data in some of the clusters were used in more than one article (e.g. clusters 1, 3, and 5), the data were reanalyzed.

The interview guide functioned as the basis for the coding process; however, if there were any gaps in the initial interviews related to the RQ, I had the opportunity to fill these gaps in the further interviews and surveys. This coding technique is typical for inductive research and consistent with my constructivist onology. The approach prioritizes the studied phenomenon, where the data and analysis emerge from the experiences shared by both the researcher and the informant (Charmaz and Belgrave, 2012). However, some of the themes in the interview guide referred to theories (for example the NPT); therefore, some of the data were coded based on the applied theory. I mixed several coding

methods, thus conducting eclectic coding (Saldaña, 2013). Overall, in the project, I used first-cycle methods – that is, inductive coding, which occurs during the initial coding of data – and further utilized *elemental methods* (i.e., holistic coding for identifying the topics). By using this descriptive coding technique, I developed an index of my data (which often consisted of several data forms) organized by the various topics and my interpretive lens and used this for further interpretation and analysis (second-cycle coding). In some cases, especially when coding stakeholders' interpretations and narratives, I used in vivo coding (Onwuegbuzie et al., 2016). I used NVivo for structuring the coding, and the themes from the interview guide were listed in the project created in NVivo. (See Appendix E for an example of coding and the articles for more details on the analysis process.)

When coding the audio files with the recorded interviews, several nodes (i.e., categories) reflecting the stakeholders' perspectives on various themes were added (Creswell, 2009). After transcribing the audio files, additional nodes were added, such as contradictions. An inductive orientation of coding was performed, working bottom-up by first coding the transcriptions into the categories from the interview guide and further identifying data meaning. This is both first- and second-cycle coding (Miles et al., 2014). For example, in the first cycle of the coding, I used descriptive coding where the code described the different information needs in SQ2. When working with SQ3, I used value coding where the stakeholders' perspectives on different terms (common operational picture and common situational understanding) were identified by profession. When analyzing the audio logs from the NPSN, the transcribed audio logs were the basis for the coding process. This was done in Excel (for making diagrams, see Article #1 and Steen-Tveit and Radianti, 2019, for the results), and the messages were coded by a description of the content (descriptive coding).

I had several question-based codes (structural coding) where I classified the data into answers to my question – for example, stakeholders' experiences with the triple-alert routine. In addition, I developed codes according to the theories as frameworks for the data collection (deductive coding). The second-cycle coding techniques used in this project were coding patterns (meta-codes for grouping similar coded data) and further grouping my codes into categories iteratively until a proper structure for the analysis was found.

In the second cycle of the coding, I used both eclectic coding (for refining the decisions I made in the first cycle) and pattern coding. The data were discussed and organized to identify patterns and themes as an interpretive and iterative process. An example is the audio logs from the NPSN, where the classification and reclassification of the messages were discussed until a stable, unique category framework emerged. In the qualitative interviews, the different nodes were generated into a more detailed coding structure for identifying patterns and similarities between stakeholders and organizations. Further, in the second cycle, the coded data were assessed and compared with theory. All the data were descriptively coded gradually based on the emerging framework that constitutes the contribution of this dissertation, ultimately resulting in three distinct elements of the framework (Chapter 7).

5.5 Validity issues

When evaluating the quality of an interpretive study, one cannot apply the same validation criteria as for positivist studies (Munkvold and Bygstad, 2016). By utilizing validity strategies, one can increase the capability for judging the results and provide credibility for readers (Creswell, 2009). During the data collection and data analysis, I used Klein and Myers's (1999) seven validity principles for IS interpretive field studies. Table 19 shows how I have addressed these principles.

Table 19: Klein and Myers's (1999) applied validity principles

No	Principle	Focus	How it was addressed in this project
1	The fundamental principle of the hermeneutic circle	The iterative interpretation of the interdependent meanings of the parts and the whole they form	I analyzed the various data collected and assessed the identified topics for building an understanding of the working processes for developing a common situational understanding. Further, I conducted data collection and data analysis through multiple iterations.

2	The principle of contextualization	The reflection of the social and historical background of the research setting	A thorough investigation and descriptions of the contexts are provided in the published papers and this dissertation. The stakeholders' reflections are emphasized in this dissertation project and reported in published papers.
3	The principle of interaction between the researchers and the subjects	The reflection on how the data were constructed through the interaction between the researcher and the informants	As a former emergency dispatcher, I have an understanding of the studied phenomenon. These insights may have influenced my interpretations. This is referred to by Walsham (1995b) as a double hermeneutic. The informants and I had a two-way relationship in some parts of the interview. This also challenged my current understanding of the phenomena through the stakeholders' perspectives. I discussed my findings with colleagues in academia (at conferences and workshops) and former colleagues from the emergency management domain. I often used direct citations (from the transcriptions) in the published papers so that readers can assess my work
4	The principle of abstraction and generalization	The application of the first and second principles to theoretical understanding of the phenomena under study	The study objective was to contribute to the IS and EM literature. By approaching the results using different theoretical lenses, and based on my contextual and theoretical understanding, I could develop the framework described in Chapter 6.
5	The principle of dialogical reasoning	The sensitivity to potential	The initial coding was partly based on theory and the interview guides. During the process of data collection, I modified the coding schemes

		contradictions between the existing theory guiding the research design and the actual findings	according to the emerging data. For example, in Article #5, a category termed “situational awareness” was added to the initial coding (i.e., the four domains of NPT). During the project period and research process, my understanding of the theoretical concepts increased. These new insights guided the next rounds of data collection and further affected the interpretation and analysis of the data.
6	The principle of multiple interpretations	The sensitivity to possible differences in interpretations and experiences among informants	I have emphasized the stakeholders’ different perspectives – for example, various perspectives among stakeholders within different organizations are emphasized in the published articles.
7	The principle of suspicion	The sensitivity to the possible biases and distortions in informants’ interpretations	I used several data sources for validating the aspects in this dissertation project. For example, I reviewed many evaluations of real events that underpin the stakeholders’ perspectives. If there were any unclear issues, the informants were contacted through email.

Another evaluation framework for interpretive research has been proposed by Guba and Lincoln (2001), involving the following criteria: (1) credibility, (2) transferability, (3) dependability, and (4) confirmability. By credibility, the authors refer to the parallel between informants’ constructed reality and the reality presented by the researcher. The credibility of this dissertation project was ensured by using several data sources (interviews, surveys, audio logs, observations, document reviews). I also sent quotation checks to the informants presenting both the quote and the context in which the quotation was used. Such feedback from the informants (i.e., member validation) was important for

ensuring that my interpretations and descriptions were meaningful for the informants, which is a recommended practice in interpretive research (Bygstad and Munkvold, 2011). By performing member validation, I could validate my understanding of the informants' experiences and that it would be expressed properly in the related publication. In the Mandal exercise (section 6.8), in addition to quotation checks, I used member validation to check the facts about the organization and management of the exercise. I did not receive any feedback that required modification of the manuscript drafts.

Further, I discussed my results with stakeholders whenever I got the chance. For example, since I worked part-time as an emergency dispatcher until 2020, I had the opportunity to discuss my findings with EM professionals. I have participated in several practitioner forums, both as a participant and as a presenter. My data has been available for peer review by researchers familiar with the EM domain by presenting my work at peer-reviewed conferences and in relevant journals. I discussed the findings with my supervisors at all stages of my data collection.

By transferability, Guba and Lincoln (2001) refer to the process that ensures the usefulness of findings beyond a study. In this project, I have thoroughly described the research context, the technology in use, and stakeholders' professional tasks and goals. I used extreme weather events as research scenarios for understanding the working processes; however, several of the findings can be applied in other complex multi-organizational scenarios as well. For example, several results present how stakeholders can prepare and develop a common situational understanding in general.

By dependability, Guba and Lincoln (2001) refer to the documentation of the chosen methodology and interpretive process for providing a possibility for the reader to understand this process. I documented the data collection methods and the data collected by creating map structures on my computer, databases in NVivo, and a literature database in EndNote.

By confirmability, Guba and Lincoln (2001) refer to the insurance that data and interpretations are constructed in the reality/study context and not as a result of the researcher's mind. In all my published papers, I have described how I moved from data collection and analysis to reaching my results. I have been a part of a

research project (the INSITU project) that has many similar focus areas as in my project, and by participating in this project, I was able to present and discuss my findings with both researchers and practitioners. In this way, potential biases in my interpretations could be discussed and corrected. For example, my experiences as a practitioner constitute an important factor regarding my interpretations, and the discussion with researchers and practitioners from other fields provided me with reflections on my views. Also, different theoretical lenses guided my understanding and description of my results and thus helped me navigate my sensemaking process.

5.6 Ethical considerations

This project concerns individuals' perspectives, work practices, and capabilities. Answering questions regarding these themes might reflect very personal thoughts, and throughout the research process, I reflected on several ethical issues as presented by Kvale and Brinkmann (2009).

The *purpose of the data collection* must not merely be discussed concerning the scientific value of knowledge the interviews will result in. It is also important to consider how the research affects the stakeholders participating. For example, informants must not be harmed in any way whatsoever, and one must prioritize their dignity at all times. Further, the purpose for data collection has to be clear, and the data must not be outside the original purpose without re-asking for consent from the informants.

In the *planning process*, I made several preparations that helped the participants be aware that they were participating in a research project and informed them of the project purpose. The project was approved by the Norwegian Centre for Research Data, and as part of this, I developed an information letter and collected written informed consent from the participants before the data collection. Anonymity was offered to all individuals participating. Walsham (2006) suggests a challenge regarding confidentiality – namely, roles or functions that might be easy for people to identify. In some of my interviews related to specific exercises (for instance, the Mandal exercise described in section 6.8), this might be a fact. However, the participants were aware of this and communicated by member validation that this did not concern them.

When *conducting the interview*, I followed several steps to make the interview a positive experience for the participant. Also, I repeated that it was voluntary to participate and that the right to withdraw from the interview process was granted. In the *transcription process*, the confidentiality perspective must again be addressed. To protect the confidentiality of information, whenever the informants shared confidential or sensitive information, this was not included in the transcription and the analysis. For example, on two occasions, I did not transcribe the full interview because the interviewees told me more than I needed to know due to frustrations regarding several issues at their workplace.

During the *analysis process*, I always processed the information in a highly aggregated level so that the information did not refer back to the informants. Deidentification was an important component during the processes. Also, I always sent interview quotations to the informants for member validation before including these in my publications.

When *reporting and publishing* the results, I have considered that there are no negative consequences for either the organizations or the stakeholders. The interview and survey materials were fully anonymous and did not include sensitive or confidential information.

6 Results

To address the RQs introduced in section 1.1, different areas of the EM domain have been investigated, resulting in seven scientific publications. Six of these constitute the core focus of the dissertation (listed in table 20). The papers have been published in scientific journals and international conference proceedings. The publication outlets reflect the multi-disciplinary perspective of the project, combining IS and EM research. In addition to the scientific articles, the results from a study of an exercise with first responders in the city of Mandal are presented in section 6.8. This study focused on information sharing among the first responder agencies (police, fire, and ambulance) during regular small-scale exercises and how this contributes to SMM and increased knowledge of each other's goals and tasks. A summary of these results was published in a Norwegian practitioner journal for the police.

The publications are listed in table 20 and are further elaborated in sections 6.1 - 6.6, which describe the focus, findings, and contributions of each paper. The full-text articles are included in Appendix G.

Table 20: Scientific publications

#	Article
1	Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *Using audio logs for analyzing the development of a common operational picture in multi-agency emergency response*. In Proceedings of the 53rd Hawaii International Conference on System Sciences, Maui, HI (USA).
2	Steen-Tveit, K. (2020). *Identifying information requirements for improving the common operational picture in multi-agency operations*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management Conference, Virginia Tech, Blacksburg, Virginia (USA).
3	Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management, Virginia Tech, Blacksburg, Virginia (USA).
4	Steen-Tveit, K., & Munkvold, B. E. (2021). From common operational picture to common situational understanding: An analysis based on practitioner perspectives. *Safety Science*, *142*, Article 105381.
5	Steen-Tveit, K. (2022). *Using a public safety radio network for information negotiation between the three-tiered command and control structure*. In Proceedings of the 55th Hawaii International Conference on System Sciences (Virtual Conference).
6	Steen-Tveit, K., Munkvold, B. E., & Radianti, J. (2021). Using live video for communication between lay bystanders and emergency dispatchers in command and control centers. *International Journal of Emergency Management*. Vol. 17, No. 2, pp. 154–176

In addition to the six papers listed in table 20, my first paper developed as a Ph.D. student was presented as a work in progress paper at the 2019 Information Systems for Crisis Response and Management Community Conference (Steen-Tveit and Radianti, 2019). Titled "Analysis of Common Operational Picture and Situational Awareness during Multiple Emergency Response Scenarios," the paper discusses the importance of SA and a COP and uses audio logs from a full-scale multi-organizational exercise for providing analysis for understanding how stakeholders communicate to build a COP in unpredictable and complex working environments. While developing this paper, I understood the complexity of common situational understanding and that the COP term needed to be further investigated. Based on these insights, I developed Article #1 together with my supervisors, using the same empirical case.

Table 21 shows how the published results address the various SQs and, as a whole, answer the main RQ raised in this dissertation. The grayscale indicates to what degree the paper addresses the particular SQ.

The SQs are as follows:

- SQ1: How can evaluations after full-scale multi-organizational exercises be carried out for analyzing stakeholders' SA and COP?
- SQ2: What information is important to share, and how, for building a COP in multi-organizational emergency collaboration?
- SQ3: What information and structures are needed for EMOs to create a common situational understanding in response to complex emergency events?
- SQ4: How can different stakeholders utilize IS for communication and data collection to enhance collaboration and achieve a common situational understanding?

Table 21: Relationship between paper contributions and the research questions

Paper	**SQ1**	**SQ2**	**SQ3**	**SQ4**
Article #1: Using audio-logs for analyzing the development of a common operational picture in multi-agency emergency response				
Article #2: SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise				
Article #3: Identifying information requirements for improving the common operational picture in multi-agency operations				
Article #4: From common operational picture to common situational understanding: An analysis based on practitioner perspectives				
Article #5: Using live video for communication between lay bystanders and emergency dispatchers information collection in command and control centers				
Article #6: Using a public safety radio network for information negotiation between the three-tiered command and control structure				

In addition, the results from the study of the Mandal exercise (see section 6.8) contribute to SQ1 and SQ3.

6.1 Article #1

Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *Using audio-logs for analyzing the development of a common operational picture in multi-agency emergency response*. In Proceedings of the 53rd Hawaii International Conference on System Sciences, Maui, HI (USA).

Focus. The paper is based on findings from observing an FSRE involving multiple terror incidents that aimed to train cooperation among the stakeholders in the field. SQ1 concerns how evaluations can contribute to better awareness of how to enhance the COP in multi-organizational operations. Training and evaluations are important elements for improving plans, policies, and practices (Weiss, 1999). The literature points out that effective evaluations of collaboration exercises are difficult; however, it is one of the most important steps for achieving a successful multi-organizational operation, as the involved agencies must build and maintain a COP. By utilizing a good evaluation method, the results can provide a positive change in the organizations.

The empirical basis for the paper was a case study of a full-scale multi-organizational exercise conducted in 2018. Multiple qualitative methods were used, combining observation, audio-log analysis, and validation with stakeholders after the exercise to clarify results. The audio logs consisted of a total of 4.25 hours of communication within and between operative units and dispatchers from the first responder agencies during the exercise. The tracks showed the actual timeline with both silence and messages, and all tracks were transcribed to ensure the completeness of all messages. All sequences of the events were further reconstructed into a complete dataset and systematized with the following information: 1) the origin of the information; 2) the recipient of the information; and 3) the information content. The dataset was also triangulated with the real-time logs documented by the police during the exercise. The authors discussed and classified the messages into several categories. The categorization used an inductive method and was developed gradually through classification and reclassification based on the content of the messages until a stable, unique

category framework emerged. The process narrowed down the original 22 categories into 14 categories. The categories aim to be sufficiently specific to reflect the content of the messages, but still also generic enough to be used in other similar cases.

Results. First, the literature review conducted in this paper identified six important features for a COP using SA theory (Endsley, 1995) as an analytical lens: (1) creation and maintenance of different SA levels within the involved agencies; (2) knowledge of each other's modus operandi, including information needs, goals, capabilities, processes, and resources; (3) effective and time-specific communication of important static and dynamic environmental features, shared elements, and common critical cues; (4) harmonized terminology, both in vocabulary and software symbols; (5) the sharing of useful comprehension of the current situation and actions/action planning that is important for the collaboration; and (6) adherence to a standardized framework for communication to avoid useless information and information overload.

The features serve as a foundation for the paper's discussion on important elements for building a COP. Next, using an inductive method, 14 information categories were identified from the audio communication: situation reports, confirmation, action plan, request, action, location, contacting, no answer, offer resources, new emergency event, common understanding, report barriers, error, and information mismatch. The categories aimed to be not only sufficiently specific to reflect the content of the messages but also generic enough to be used in similar cases (De Moor, 2009).

The analysis of the audio logs revealed the state of SA in different stages of the operation and demonstrated the importance of individual SA for being able to share relevant information. For example, the information exchanges combined with the timeline illustrated how stakeholders shared critical cues (level 1 SA), requests and situation reports (level 2 SA), and planning and projections (level 3 SA) during the response.

Contributions.

The analysis of the audio logs provides insights for both practitioners and researchers in the emergency management domain concerning the dynamics of

multi-organizational collaboration and information exchanges when responding to emergencies. The information exchange phases provide an overall picture of the collaborative communication for building SA and COP. The 14 message categories constitute a methodology to analyze SA and COP by identifying the bottlenecks and comparing the six COP features in the communication structure during the different phases of an operation and thus increase the potential for improvement. The methodology offers an important supplementing tool for evaluating real events and exercises by providing a post hoc analysis of real-time communication related to establishing a COP. In addition, the suggested 14 message categories contribute to an overview of what information is shared at what time in the different phases and to the identification of the most active information exchanges in a multi-organizational emergency response.

6.2 Article #2

Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise.* In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management, Virginia Tech, Blacksburg, Virginia (USA).

Focus. Article #2 focuses on the difficulties of observing stakeholders' SA during emergency response operations and aims to contribute to existing methods for collecting data for evaluating SA (SQ1). In this case, the SA aspect concerns the focus on individual stakeholders who have to evaluate a number of cues for assessing the situation and for immediate decision making.

We present an example of real-time data collection using an SMS-based survey (for immediate attention) during a multi-organizational field exercise for analyzing the formation of SA and a COP among stakeholders in multi-agency EM. The involved stakeholders used the NPSN as a common communication tool.

The empirical basis for the study was a field trial (see figure 8) using an SMS-based survey for near real-time data collection among important decision-makers during an FSRE involving a forest fire scenario. The SMS consisted of a link to eight questions concerning the stakeholders' SA and whether they had access to

sufficient information. This SMS survey was delivered to 15 key stakeholders at two different stages during the exercise (see section 5.3.4).

Figure 8: Exercise timeline and main events

The questions in the SMS survey (table 22) were based on some of the important elements in achieving SA such as receiving information (questions 1,2 and 3), how to comprehend the information (question 4), prediction of future status (question 5) and knowledge about available resources (questions 6 and 7). Some of the questions were designed as multiple choice and also with the possibility to include a free text response to elaborate.

Table 22: Questions in the SMS survey

Number	Question
1	Have you been provided with sufficient information to form an understanding of the situation?
2	Who gave you the latest situation report?
3	How did you receive the information?
4	How do you understand the scope of the fire?
5	Which of the following critical community features do you believe is threatened?
6	Are all necessary resources for managing the situation present?
7	Do you know the location of the other resources?

Also, qualitative interviews of nine of the same key stakeholders were conducted after the exercise in order to obtain their perspectives of the data collection method. The responding stakeholders consisted of participants from first responder services (police, fire, and health services), two involved municipalities,

the County Governor's office, and the Red Cross. All these actors had some degree of authority to make decisions.

Results. The answers from the first SMS survey (distributed one hour after the start of the exercise) indicated that 57% of the stakeholders perceived having sufficient information during the first hour. The information flow was characterized by being communicated on-site, and the lack of shared IS (beyond the NPSN) showed that verbal descriptions are insufficient to form a SA in such a complex scenario. Also, it may indicate that the information flow did not fulfill the different actors' internal information needs. The answers from the second SMS survey (distributed three hours into the exercise) showed that most of the stakeholders had an increased understanding of the situation and experienced having sufficient information about the situation.

The interviewees stated clear opinions about the method and were mainly positive and expressed an understanding of the purpose. The majority also appreciated the goal of the SMS surveys, considering that the evaluation of SA and COP is a difficult and important area for practice.

Contributions. Article #2 contributes with lessons learned and recommendations for future real-time data collection using an SMS-based survey, and the method provides the possibility of measuring the differences in stakeholders' SA of important elements of an emergency at given stages in the operation and of further comparing this information to evaluate to what degree a COP has been established. To some extent, the article also contributes perspectives on information sharing between the stakeholders that form SA and indicates that verbal information sharing alone is insufficient. The results also showed some limitations of using the method; for example, collecting data from a link instead of personally asking the informants (such as in SPAM and SAGAT) limits the possibility of asking follow-up questions and clarifying answers. Also, some informants perceived the SMS-based survey as intrusive while performing their tasks. Further, such a method should be implemented cautiously to maintain the balance between the use of too simple and too complex questions and response options.

6.3 Article #3

Steen-Tveit, K. (2020). *Identifying information requirements for improving the common operational picture in multi-agency operations*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management Conference, Virginia Tech, Blacksburg, Virginia (USA).

Focus. The third paper aimed to identify common information requirements and discusses an information sharing structure between multiple EMOs. I used extreme weather scenarios as cases to elicit the information needs that would support the establishment of a COP. The study was based on implications from Articles #1 and #2 and aimed to answer SQ2 (i.e., What critical cues/information needs are important to share, and how, for building a COP in multi-agency emergency collaborating operations?) by conducting individual qualitative interviews of twelve first responders and stakeholders from several municipalities and supporting organizations. In addition, a survey was sent to three other organizations which are characterized as support organizations (i.e., the Ministry of Justice and Public Security, the Agder County Governor`s office, and the Civil Defence) because they are not responsible for handling the crisis at the operational level.

The answers from both the interviews and the survey were categorized based on the selected scenarios and were further classified into information requirement categories using an inductive method. The classification was based on the informants' answers and not on universal definitions. For example, when an informant said, "*which area is affected by the forest fire*," this was classified into the information requirement category "location." Another example is that roads, power, and networks were classified under "critical infrastructure." Finally, the information requirements were compared, and the common requirements were determined and described. The data from both interviews and survey were coded and analyzed in NVivo (QSRInternational).

The article starts by presenting and discussing relevant literature on SA and COP. Then it presents a summary of the current practice of information sharing and points to implications and limitations related to the existing literature. Further, based on the literature review and the interviews, the paper provides

practitioners' perspectives on how a COP can hinder SA because the COP concept generally includes all available information and does not prioritize the relevant elements that ought to be shared. This must then be filtered through the involved stakeholders' SA (that is, a subjective state of mind), which demands extensive knowledge of each other's information requirements. Without this prioritization, the involved stakeholders suffer from information overload, which again challenges their cognitive capabilities. The stakeholders are characterized by different disciplines, tasks, goals, and working modes. Therefore, the COP concept, as it appears in the literature, cannot guarantee that the involved stakeholders will achieve common situational understanding, as they must have the same awareness of what is happening. The paper argues that it is necessary with preparation and working methodologies, such as predefined information categories and a structure for information sharing to establish a successful COP. For example, an information-sharing structure called the "window report" (Borglund, 2017) was used to demonstrate how and with whom information can be shared as a conceptual structure for the information presented.

Findings. The analysis of Article #3 revealed eight common information requirement categories that constitute an important foundation for information sharing in the context of extreme weather events: Location, Critical infrastructure, Information of possible victims, Evacuation of possible victims, Resources, Weather forecast, Critical buildings, and Situational development. The analysis of the different information requirements demonstrated that it is not possible to operate with a single COP, as all the organizations involved and their need for an operational picture must be considered. However, there are many common features in the identified information requirements (demonstrated in the categorization), which should be the foundation for sharing common information and building a COP.

Contribution. Article #3 contributes to the research on information sharing in EM by identifying information requirement categories for emergency organizations in different contexts. This facilitates the inclusion of a COP perspective at the strategic level of EM.

6.4 Article #4

Steen-Tveit, K., & Munkvold, B. E. (2021). From common operational picture to common situational understanding: An analysis based on practitioner perspectives. *Safety Science*, 142, Article 105381.

Focus. Article #4 presents practitioner perspectives on the concepts of COP and common situational understanding and their relationships and further suggests a conceptual framework for how to get from one to the other. Choosing this research as the next step following Article #3 was driven by the indication that the practitioners had a clear assumption of the differences between a COP and a common situational understanding. Since SA is a subjective state, and the different organizations involved have different information needs for their organizational-specific tasks and goals, it is necessary to specify the elements in the stages of building a COP and reaching a common situational understanding (SQ3). There is no univocal definition of either common situational understanding or COP in the scientific literature, and the findings of Article #3 support the notion that it is impossible to operate with a single COP. This underpins the importance of identifying the important elements of common situational understanding and COP and exploring how this can support both common and agency-specific operational information needs.

Investigating such complex phenomena required in-depth knowledge; therefore, a combination of data sources was used. First, a thorough literature review was conducted. Further, semi-structured interviews were conducted (including an interview with a GIS system vendor), combined with visits to some of the workplaces where the technology was demonstrated, a new analysis of the audio logs from the act of terror exercise in 2018 (ref. table 18), and a document review of 21 public reports and evaluations of real emergency events.
The interviews were conducted based on a semi-structured interview guide with open questions. The interview guide was divided into themes regarding the stakeholders‘ process to build common situational understanding in their organization; this included how they prepare for handling crises, their current knowledge on other stakeholders‘ information needs, the terminology used, and what constitutes a COP and common situational understanding. The questions were related to a forest fire scenario, however, the answers could also be related

to other scenarios. For the system vendor, the interview guide covered the different GIS features in use by first responder agencies and future possibilities. Also, opportunities and capabilities for collaboration and information sharing within the different systems were mapped. Since the NPSN is the main communication platform for the first responder services, interviews with managers in NPSN were conducted to get clarity on the status of different organizations‘ use of the NPSN. Except for the online group interview with NSPN, all interviews were recorded and transcribed in full and analyzed in NVivo (QSRInternational). For the online interview, detailed notes were taken during the meeting. Since these interviews followed another interview guide, the answers were not included in the analysis in NVivo.

The content of the audio log messages was reviewed to identify examples of how verbal information sharing of geospatial information supported the development of a COP. Further, the messages were categorized into 6 main categories based on the content. The categorization was inductive and was developed gradually through classification and reclassification based on the content of the messages. This resulted in the following categories: (1) Information on emergency events; (2) Action/action planning, which involves location; (3) Communication on different locations, e.g. where is the incident, where are the resources, meeting place, etc.; (4) Request for various resources, can also be related to a specific area/location; (5) Situation reports; (6) Contacting/confirming/request of information.

Findings. The results of this study identified several important elements included in the conceptual framework. First, exercises and training are important for developing SMM. Second, the COP needs to comprise several COP structures for both common and agency-specific information needs. Third, the COP must also involve scripts based on the RPD model for facilitating collaborative decision-making. Fourth, in addition to COP establishment, it is important to facilitate trading zones (i.e., “where the process of translation and negotiation takes place” [Boersma et al., 2012, p. 6]) where the involved actors can negotiate interpretations and professional views of the situation.

Contributions. Article #4 contributes to the EM field by investigating the actors’ assumptions on the concepts of COP and common situational understanding and

by providing a clearer distinction between these concepts when it comes to practice. This distinction provides an understanding of the steps involved in getting from a COP to a common situational understanding. Based on the practical view of the community of responders, the framework also contributes to emphasizing important steps when developing new procedures and tools in practice. The findings from this study imply a strong need for improvement in how to establish common situational understanding, and the proposed framework can inform planning processes on how to make improvements based on the users' perspectives.

6.5 Article #5

Steen-Tveit, K., Munkvold, B. E., & Radianti, J. (2021). Using live video for communication between lay bystanders and emergency dispatchers in command and control centers. *International Journal of Emergency Management*. Vol. 17, No. 2, pp. 154–176.

Focus. Article #5 reports how enhanced possibilities for new information collection can be incorporated into existing work processes and aimed to address SQ4. Choosing this topic as the next step was driven by implications for further investigation in Articles #3 and #4. The findings from these papers suggest that even if it is necessary and desirable to have the possibility of sharing and receiving information through technology for enhanced SA, it is important to consider the possible effects of this information on the complex work processes in EM, such as information overload (Neustaedter et al., 2018). Thus, this understanding was relevant for the overall research topic in this dissertation.

To investigate this, a study of how the novel use of live video streaming as an information collection tool influenced the complex work processes in Norwegian CCCs was conducted. The CCCs included were fire and health CCCs engaged in projects involving the use of live video for communication with callers from the incident scene. The study design combined qualitative interviews and observation of the live video system. The informants were characterized as expert users, as they had in-depth knowledge of the implementation, evaluations, and use of the live video system in their CCCs. The analysis was based on NPT's (May, 2006, 2009) four domains (coherence, cognitive participation, collective

action, and reflexive monitoring) guiding the identification of workflow issues and the usefulness of the system. The observation took place in one of the fire CCCs where the system was demonstrated and discussed in the CCC workspace. Two emergency dispatchers here showed how they use the system and answered questions. In addition, an audio log from a medical CCC was collected as an example of the use of dispatch guidelines in the initial phase of a response operation.

The interviews were translated from Norwegian into English, and further coded in NVivo (QSR International). The data analysis was done in two iterations. First, the interview statements were manually coded into the four NPT domains, a Context category, and features related to SA. All themes were related to the use of live video in the actual NPT domain, based on the informants` reflections and examples from practice. Second, an inductive method was used to code the data included in each theme into different stakeholders` perspectives and similarities and dissimilarities within each theme (see table 23).

Table 23: Themes used for the initial analysis process

Domain	**Themes**
Context	Workflows, procedures/structures, description of various systems, use and interoperability, and additional systems
Coherence	Impact on SA, barriers, thoughts on use and functionality, sensemaking of the system, advantages, trust, organizational goals
Cognitive participation	Collective thoughts on implementation, use, how the system was introduced, resistance, future development
Collective action	Influence on workflows and caller interaction, required knowledge, flexibility, collaboration, additional information, decision making, actions, trust
Reflexive monitoring	System`s effect on current and previous practices and procedures

Findings. The analysis identified several elements related to workflow, the four domains of NPT, and SA features. First, there are many similarities in the CCCs' workflows, despite their different EM domains. Second, as long as the system is not fully integrated into the existing work processes, the live video system serves

as an additional and optional information collection tool. Third, a data collection tool such as the live video system can make a clear contribution to the data collection in the CCCs as long as it is well incorporated into the existing routines.

Contributions. The study contributes to knowledge of how to facilitate the incorporation of an information system such as the live video system into the organizational everyday routine such as in the CCCs and thus become normalized in complex workflows. NPT application constitutes a novel contribution to the theoretical body of knowledge, as it appears in the literature that NPT has so far been exclusively applied to research on healthcare innovations. Article #5 shows that NPT can be applied in EM research; however, the additional *Context* category appears to be especially important because this category maps the common aspects of workflows among the involved organizations. This is important for discussing the four NPT domains, as the incorporated system must be used for the same purpose in all involved organizations.

6.6 Article #6

Steen-Tveit, K. (2022). *Using a public safety radio network for information negotiation between the three-tiered command and control structure*.
In Proceedings of the 53rd Hawaii International Conference on System Sciences.

Focus. Article #6 is built on some of the findings of Articles #3, #4, and #5 that information sharing between EMOs is hard to integrate into software as an exhaustive solution as some information must be verbally negotiated between the stakeholders, and the role of a secure radio network is highly important to accomplish a shared understanding of situations. Thus, the information presented in the COP (that is mostly factual) is insufficient for different stakeholders to build a common situational understanding (SQ3 and SQ4). Further, the study acknowledges that different stakeholders collect information that fits their professional standpoint and therefore develop different perspectives of the situation. Following this, the sensemaking process is an important component when focusing on information sharing to achieve a common situational understanding (Wolbers and Boersma, 2013). The study aims to identify information elements beyond the factual (e.g., semantic and pragmatic levels)

that are important to negotiate between the involved stakeholders, at the operational, tactical, and strategic levels, for extending the information provided in the COP. Further, how this can be done by using a secure radio network is focused on.

The empirical basis for this study includes interviewing 33 Norwegian EM stakeholders from different levels of the C2S. In addition, a survey from a multi-organizational exercise focusing on common situational understanding was used to supplement the interviews. The respondents of the survey were involved in a tabletop exercise involving three large forest fires occurring simultaneously in different areas of Southern Norway and used the NPSN for verbal communication during the exercise. A survey consisting of 28 questions regarding the use of the NPSN was sent out to all participants directly after the exercise. A total of 29 participants had used the NPSN and answered the survey. The interview guide was based on transcriptions of audio logs from a real forest fire in Southern Norway in May 2020. The author listened to and transcribed all telephone and radio communication between the involved stakeholders from the first hour of the operation from a fire CCC. The communication was presented in the interview guide as an objective summary (due to confidentiality) of the information exchange between different actors. Some examples of communications from the beginning of the incident were: *1. Location clarifications. 2. Emergency event – fire; what is burning - bushes. 3. Possible time since the origin. 4. Fire development. 5. Possibility to extinguish the fire. 6. Wind direction.* For each information-sharing sequence (emergency dispatcher talking to the caller/lay bystander or other stakeholders), different questions were asked related to the information. For example, if their organization should be involved in that particular phase they were asked about who they would contact, decision-making, the use of NPSN, and additional information needs.

The interview guide also had a semi-structured section with several open questions related to verbal communication in NPSN. All interviews were transcribed in full, coded, analyzed in NVivo, and translated from Norwegian into English. Firstly, the data were coded into the following categories: (1) what C2S he/she represented, (2) use/experiences with the NPSN, (3) communication/information sharing structures, (4) needed information/lack of information, and (5) additional technologies. Secondly, within each communication sequence from the forest fire scenario, the coding included the following categories: (1) information needs, (2) alert of internal and external stakeholders, (3) decision making, (4) information requiring negotiation (see table 2 on how the information was structured), and (5) possible misunderstandings. Finally, the section with open questions was coded into the following categories: (1) Ideal message exchange, (2) ideal participants in the call group, and (3) reflection on different participant views. The different categories were eventually compared between the different C2S and analyzed using an inductive method. The answers from the survey were listed and coded into the following categories: (1) reflections on how to use common call groups, (2) actions/decisions based on the information flow in the common call group, and (3) benefits/disadvantages of being a part of the communication in the common call group.

Findings. First, the analysis showed that all three C2S are dependent on some of the same information for building a basic understanding of the situation. This constituted a heuristic rule (IERO, i.e., Incident, Exact position, Resources, Objective description; table 24). Second, the study identified several information areas that must be negotiated for developing a common situational understanding. For example, the different stakeholders' views of the severity of the situation are important to be able to negotiate. Also, the analysis indicated that there is a logical connection between the different information areas through the operational, tactical, and strategic C2S. Access to a secure radio network for verbal communication was shown to be important for sharing important common information elements between the stakeholders, negotiating a common understanding, and monitoring important elements in the operation.

Table 24: The IERO structure

Incident	Confirmation or update/rejection of the situation
Exact position	Confirmation or update/rejection of the position and clarification of the GPS format
Resources	Estimation of the need for resources from a multi-organizational perspective
Objective description	Description of the elements in the environment, i.e., civilians, victims, dangers, damage

Contribution. The study offers lessons on how to connect the three-tiered C2S with up-to-date information negotiation for collective sensemaking and common situational understanding. The contribution involves what kind of information should be negotiated (i.e., the stakeholders negotiate their perception of elements such as the level of severity), how to facilitate the communication paths by using a secure radio network, and how to solve some of the existing logistic issues (i.e., work overload for incident managers) by introducing the function of information managers.

6.7 The relationship between the articles

The six articles aim to answer different SQs that together constitute a holistic view of the phenomenon. In this way, the papers both contribute to the overall research objective and provide a logical construction of the framework on how to get from a COP to a common situational understanding.

Table 21 presented earlier in this chapter illustrates how the different papers address the RQs.

The findings in each paper provide a natural angle for the next paper. Figure 9 shows how the main findings and SQ are related. See also figure 6 for a reminder of what the data collection clusters constitute.

The analyses in Article #1 and Article #2 documented different characteristics of EM such as the information-sharing practices. This resulted in the need for increased knowledge of the stakeholders' mutual information requirements during information sharing related to the COP (features addressed in Article #3), which is included in SQ2. Article #1 also identified what kind of categories of information was shared and with whom at the different stages of emergency

operations. For example, a finding in Article #1 was that some personnel in the organizations played a key role in reporting situations (e.g., incident manager in fire and rescue services). This became the basis for the discussion on the "window report" sharing structure in Article #3, in addition to the identification of the common information requirements. Article #3 confirms findings from previous research that with a single COP, it is insufficient to provide a holistic operational picture for all stakeholders involved. Further, the article documents that some of the information shared verbally would benefit from being displayed in a common GIS interface. Several of the respondents from the first responder agencies referred to verbal collaborative communication as the best way to build a common situational understanding, which then became the basis for Article #4

The results in Article #4 document that the COP serves as a baseline for common situational understanding, as it consists of IS for information collection, communication, and visual support (such as GIS). Therefore, the paper identifies the need to explore the stakeholders' views of how to successfully implement such information access into their complex working processes (Article #5). The paper also identifies that common situational understanding is developed by the negotiation of information elements between the stakeholders in "trading zones" (Boersma et al., 2012). Based on this and SQ4, which concerns how stakeholders can utilize IS for collaboration and draw on professional knowledge, Article #5 and Article #6 were developed. Article #5 concerns how an IS can be normalized into complex working processes and enhance the actors' SA. Article #6 addresses the trading zone aspect using an IS (the NPSN) and identifies what information needs to be negotiated.

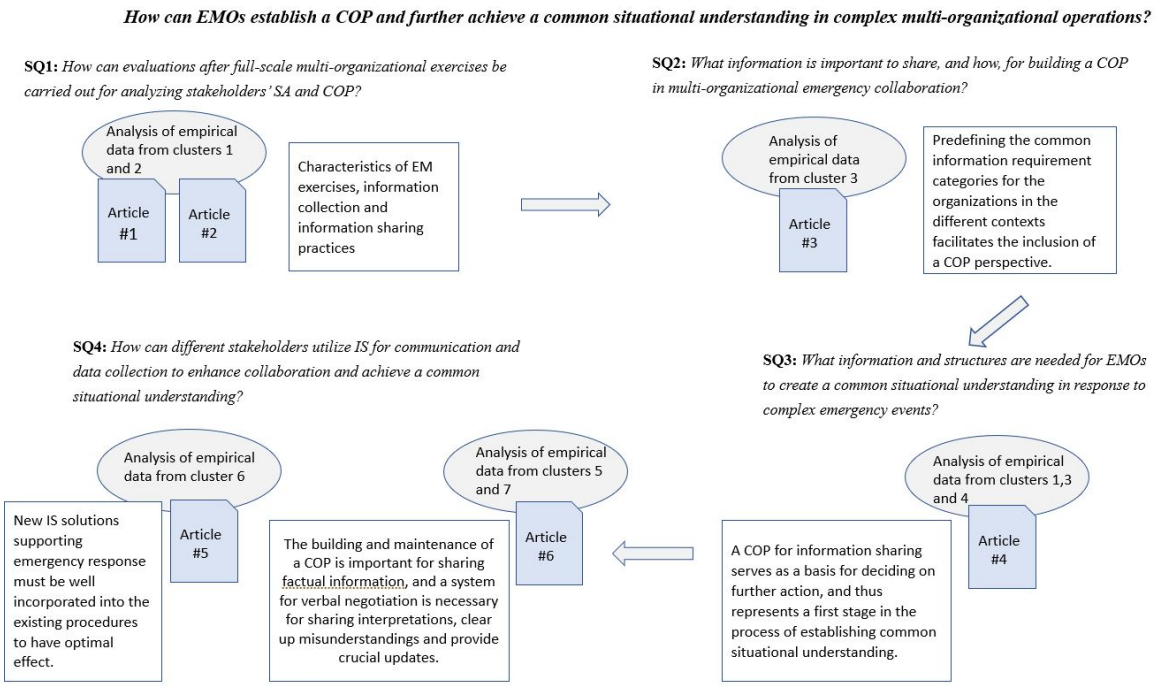

Figure 9: The connection between the articles

6.8 The Mandal exercise

I had the opportunity to enrich my data collection activity through a direct invitation from one of my informants to observe a small-scale local exercise with the first responder organizations – that is, the "Mandal exercise" involving and organized by the police, fire and rescue, and health services in Mandal city. Since the first responders in Mandal city have a strategy of training together relatively often, this was a relevant case for investigating what kind of results such practice can provide.

Focus. The Mandal exercise is a short (one hour) collaboration activity conducted several times a year, with a focus on everyday emergency events that involve all three first responder organizations. This exercise model has been a part of their routine since 2002. The exercise aims to be cost- and time-effective and contributes to increasing the knowledge about each other and the shared information needs among the different first responders. The first responders also practice information exchange in the common call group BAPS (fire, ambulance, and police collaboration call group in the NPSN) and the window report structure for information sharing. The involved stakeholders verbally evaluate the exercise on-site directly at the end.

Methods. I used observation, audio and image documentation, and interviews. I observed the exercise by following the exercise manager and IC (i.e., the police officer in charge of the emergency operation). I could listen to the traffic in the BAPS call group through the exercise and took notes and several pictures. I was also present during the evaluation after the exercise.

Directly after the exercise, I went to the different first responders' stations and interviewed the stakeholders involved. The interviews included three police officers, two ambulance personnel, and five fire and rescue officers. I used a semi-structured interview guide that included questions from the interview guide regarding the NPSN (Appendix B) and a section regarding their knowledge of each other, collaboration skills, and their perspectives on the outcome of such frequent small-scale collaboration exercises. The interviews lasted between 30 and 60 minutes. The interviews were recorded, transcribed, and analyzed in NVivo. I also received the audio logs from the BAPS call group from the local police CCC. This was reviewed, and I took notes (no transcription or analysis).

Results. The results provided valuable data regarding the use of the NPSN and are included in Article #6. Further, the results also demonstrated that the stakeholders had developed SMM. The results showed that the stakeholders experienced the following (compared to before they started with/joined the collaboration exercises):

- The stakeholders experienced increased knowledge of what is expected from them related to collaboration with other organizations.
- The communication in BAPS was streamlined and relevant; the IC did not have to control or correct the communication flow. The stakeholders had a good understanding of, and were more comfortable with, the use of BAPS.
- The stakeholders had relevant insights into what resources the collaborative organizations hold and knowledge of different equipment they have access to and where the equipment is located in their vehicles.
- The stakeholders had knowledge and understanding of each other's reactions and patterns of actions.
- All in all, the stakeholders experienced better collaboration after starting with these exercises.

Contribution. The experience and data collection from the Mandal exercise contributed to answering SQ1 and SQ3 by offering valuable insights into the effects of collaboration exercises. It contributed both in terms of how to facilitate the exercises and the SMM aspect, which appears to be an important factor for both understanding and developing the structures comprising common situational understanding in multi-agency emergency operations.

6.9 Summary of main results

The main results from the six articles and Mandal exercise are the basis for the discussion chapter in this thesis. The main results are as follows:

- The identification of information exchange categories, information-sharing practices, and working processes in multi-organizational EM.
- A method for evaluating the development of SA and COP using audio logs from a radio network during multi-organizational exercises
- The identification of several elements important for building a COP and common situational understanding, such as shared mental models, structures for information sharing and, common information requirements.
- The discussion of different features of IS that can and should be included in a COP, such as GIS, the triple alert routines, and common call groups in a secure radio network.
- Demonstrates the importance of the consideration of human factors in IS for EM.

7 Discussion: How to get from a COP to a common situational understanding

This chapter discusses the results of the dissertation project and proposes a framework for how to get from a COP to a common situational understanding. The dissertation focuses on complex multi-organizational EM using complex disaster events as scenarios, derived from several full-scale and local exercises. The publications include the specific elements of different scenarios used for this research; however, the discussion on COP and common situational understanding focuses on the general perspective.

The dissertation project aimed to investigate different stakeholders' working processes, including the use of IS, and behavioral and cognitive perspectives in the context of managing complex emergency environments. Thus, by employing SA model, decision-making theories, and NPT as the lenses, the discussion tailors empirical data and previous studies in the IS and EM domains and contributes to an enhanced understanding of how to facilitate effective collaboration across stakeholders in different C2S.

The discussion begins by demonstrating that a common situational understanding is based on a process that includes training and evaluation for the development of SMM and that SMM is a precondition for utilizing a COP. Next, the element of using different IS to build a COP is addressed. This constitutes the working processes of the strategic and tactical C2S, emphasizing the utilization of IS by stakeholders as the main tools for gaining SA and collaboration. The chapter then moves on to the development of common situational understanding. The importance of negotiation and the ability to share information at the semantic and pragmatic levels is crucial for stakeholders to have the opportunity to obtain a shared understanding of the elements in a COP. These communication processes should mainly originate from predefined structures/procedures for message exchange.

Based on these results, a conceptual framework consisting of three fundamental elements of how to get from a COP to a common situational understanding was developed: (1) training for SMM, (2) building a COP, and (3) negotiating a

common situational understanding. Figure 10 shows all three necessary elements for developing a common situational understanding.

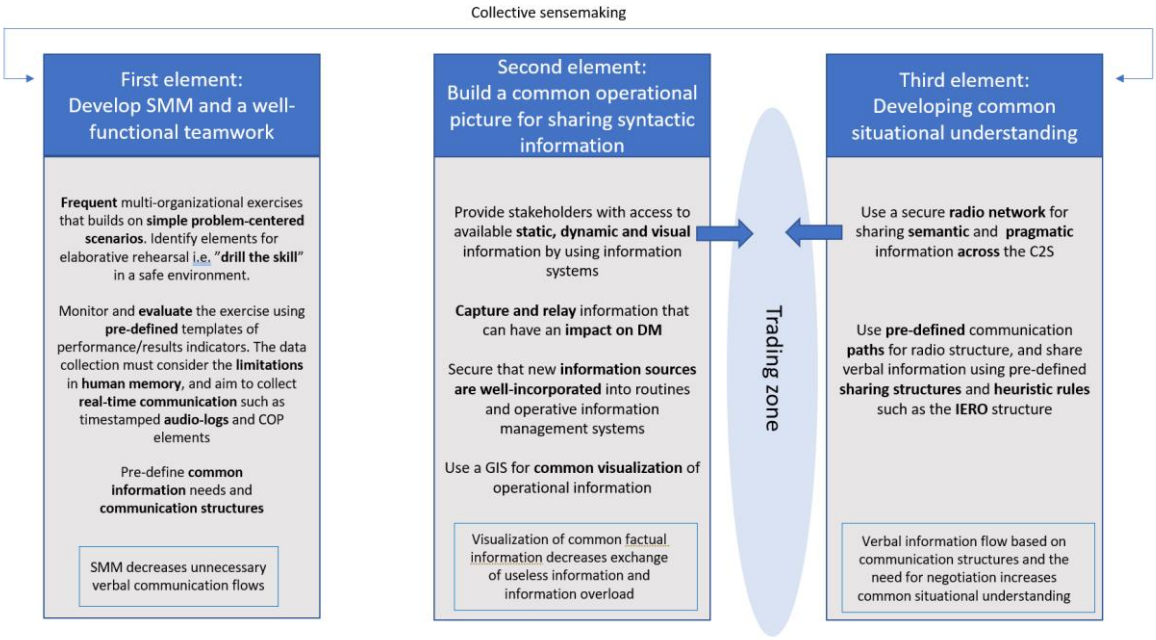

Figure 10: The three elements for developing a common situational understanding

7.1 First element: Training and evaluation for the development of SMM

The results of this dissertation project demonstrate that training and evaluations after multi-organizational exercises can develop SMM and contribute to an enhanced COP and common situational understanding in future emergency responses.

The literature points out several challenges for effective evaluation after multi-organizational exercises, such as the difficulty of objective evaluations due to the different understandings and knowledge among the stakeholders involved (e.g., Gryth et al., 2010; Imoussaten et al., 2014). One of the core challenges related to cross-organizational EM is the understanding of the logic behind different situational elements (Lee et al., 2009), which can be explained by the lack of SMM; thus, the individuals' SA is incompatible and conflicting (Hwang and Yoon, 2020). SMM enables stakeholders to function together cognitively (Moon et al., 2020) and provides a common "map" of the structures that give rise to which plans would be selected in a specific situation (i.e., a pattern-matching

mechanism). SMM can be developed by training to “drill the skill” by, for example, performing it practically or by a concept-mapping intervention. Concept mapping has a positive impact on the development of shared cognitions (Santos et al., 2021).

Article #1 contributes with a method for analyzing real-time communication between stakeholders to provide more objective evaluation material. However, the analysis of the message exchange in this exercise also documented several categories that cannot be communicated and handled through a COP (such as report barriers and several of the request messages). These information elements and message exchanges must be solved by negotiation (i.e., interpretations and implications from different stakeholders) and well-developed SMM. This finding is a contribution to the previous literature (e.g., Gryth et al., 2010; Imoussaten et al., 2014) because it points to important collaboration elements that must be considered somewhat separate from the COP requirements. Such collaboration skills require frequent multi-organizational training focusing on communication structures and the development of SMM.

The content of the audio-log messages revealed several incidents where the involved stakeholders seemed not to be “on the same page.” This can be explained by the lack of SMM; thus, the individuals’ SA was incompatible. For example, in the exercise presented in Article #1, there was a mismatch between the understanding of the situation, where one EMO treated it as an ordinary traffic accident while others were treating it as an “ongoing life-threatening violence” situation (PLIVO). In a real situation, this could either lead to underestimating the situation, such as not deploying necessary resources if the situation is actually related to PLIVO, or overestimating the situation by sending full resources ready for PLIVO while the situation is actually related to a traffic accident. This shows that the understanding of the logic behind the different situational elements was limited.

In the Mandal exercise (presented in section 6.8), the four SMM levels (table 5) emerged from the data analysis and showed that the stakeholders’ mental representations overlap. These stakeholders facilitated frequent and low-cost multi-organizational exercises using simple problem-centered scenarios that enabled them to share both knowledge and practice interactions, which are

elements for better cognition of teams. The results of this dissertation project demonstrated that such training makes stakeholders aware of the knowledge other team members acquire and how they have access to this knowledge through communication. Thus, stakeholders develop transactive memory systems (Wegner et al., 1985), which complement the individuals' memories. The training further facilitated elaborative rehearsals of specific tasks, such as providing window reports. When training for time-critical complex situations, such an environment for trying and failing is necessary. These environments can also include the basic elements for DM – a combination of knowledge, experience, and facts that require shared cognitions (Khorram-Manesh et al., 2016).

The results from this dissertation project suggest that frequent training for the development of SMM is a necessary factor for the stakeholders in a multi-organizational emergency operation to achieve a common situational understanding. Further, simple and frequent training for collaboration that develops SMM also supports and expands previous research by documenting that well-developed SMM decrease unnecessary verbal communication flow (Espevik et al., 2006) and release resources (i.e., the communication flow is structured and there is limited information overload/requests/report barriers).

The stakeholders in Mandal used a somewhat self-led AAR approach (Boet et al., 2013), where the facilitator did not take overall control of the discussion. The discussion was not structured, which might be the easiest and most cost-effective method in such training scenarios. A low-structured approach for evaluation might allow for greater flexibility to capture and learn from dynamic performance, enable stakeholders to produce novel ideas (Keiser and Arthur, 2021), and lead to more effective communication processes (Tannenbaun and Creasoli, 2013). However, some of the elements in a structured approach have several advantages – for example, a more focused discussion on performance indicators such as decision-making practices. An approach that can meet both the benefits of structured and less-structured AAR can be simple predefined templates for the discussion.

Audio logs and COP elements, such as screenshots of maps, can meet the requirements for objective review media. Data collection that aims to capture the

"in situ" assessments of a situation – for example, by using SMS-based data collection as discussed in this dissertation project (ref. Article #2) – will support evaluation with real-time data reflecting the actors' SA during the exercise. This can function as a counterweight to stakeholders' post hoc rationalization. However, it is important to consider that such data collection might hamper the cost and time effectiveness of simple low-cost exercises. A distinction between simple "drill the skill" exercises and more comprehensive exercises in terms of data collection and evaluation methods is required and should be included in exercise planning.

7.1.1 Pre-defining information needs and communication structures

Coordination between the different C2S is challenging mainly due to the complexity of information exchange mechanisms at various levels (Moon et al., 2020). This is a recurring challenge both within and across the three-tiered C2S (Boin and Hart, 2010) caused by ineffective information-sharing processes due to a lack of knowledge regarding specific information needs in collaborative organizations (Munkvold et al., 2019). The heterogeneous information needs among the organizations involved cause an inability to determine what information needs to be shared (Bharosa et al., 2010).

Recall that in this dissertation project, I used extreme weather scenarios to identify the information requirement categories (Article #3). Article #3 provides an overview of relevant dynamic and static information that needs to be shared during such complex events and a communication structure for how to share the information. These information requirements were identified after a multi-organizational exercise and enabled the stakeholders to pre-define common information needs. Investigating and defining common information requirements in different contexts can provide important perspectives to consider when developing new solutions for managing complex emergencies. The results also indicated that it is impossible to operate with a single COP because it must consider the specific information elements of all organizations involved, in addition to the shared elements.

The window report structure is characterized as an effective method for developing a common situational understanding by several of the informants in

this dissertation project. The results suggest the window report as an effective communication structure for information sharing and recommend that it become a more integrated feature in working procedures. This is consistent with previous research demonstrating that using clear communication and predefined guidelines results in better decision-making facilitated by SMM between stakeholders (Edgar et al., 2021). Many public organizations lack a common structure that specifies information sharing structures across the relevant organizations. This results in collective blind spots uncovered in evaluations of real events and exercises (Boin et al., 2017). The IERO structure presented in this dissertation (Article #6) is a heuristic guideline that can secure predefined information sharing by following a template for the information needs (table 24 in section 6.6). The IERO structure is identified as the basic information needs among the three-tiered C2S and can function as an information structure when stakeholders first arrive at an incident scene or when new separate situations occur. The sharing of these initial information needs can be structured as a heuristic rule or implemented in the window report structure. The elements of the IERO structure have been proven to include additional organizations beyond first responder agencies. Thus, the window report can be extended with the IERO structure to an information sharing structure in multi-organizational EM.

Predefined information needs must also be structured and implemented in IS comprising a COP that combines both static and dynamic information known to be needed in different settings. In this sense, the COP as an object (McNeese et al, 2006) should be able to capture and relay any information elements that may impact plans or decisions to be made, such as the need for special protection before entering hazardous areas. These information categories could be pre-implemented in, for example, a GIS.

7.2 Second element: Building a COP as a foundation for common situational understanding

There is a need to focus on identifying concrete elements that facilitate information sharing in multi-organizational EM (Waring, 2018). As mentioned in section 1.1, there is no univocal definition of what a COP constitutes (Wolbers and Boersma, 2013), and there exist different perspectives on the term. For example, it is used as a collective term for many suggested technical solutions for

information sharing and data collection (Looney, 2001), and it is a continuous need for stakeholder interaction when filtering the information during a crisis into a COP (Onorati et al., 2019). This is further problematized by the fact that in complex emergencies, the stakeholders do not have enough resources to produce and share the needed information (Luokkala et al., 2017). The effectiveness of the COP is still determined by several factors, such as interoperability across the involved organizations and structures that support the processes of decision-making (Comfort, 2007). For example, strategic decision-making is one of the challenges in the strategic C2S, and making diagnoses and decisions is a challenge in the tactical/operational C2S (Boin and Hart, 2010).

The results of this dissertation project support the assumption that it is impossible to operate with a single COP for all EMOs involved in complex events. The COP must facilitate a selection of the relevant dynamic and static information that will contribute toward building custom-made COPs for all EMOs involved across the C2S. Thus, the representation of the information and predefined knowledge is also important for avoiding the exchange of useless information, as well as information overload. A finding in the dissertation project is that a basic feature of a COP must be a common visualization of different locations in a GIS. The audio logs (section 5.3.2) presented in Articles #1 and #4 demonstrated that several of the message exchange categories (such as location and other organizations' operative resources) would be valuable to be visualized and not be dependent on verbal communication. Such visualization of common factual information can decrease unnecessary verbal communication flows.

Further, the dissertation project's results show that information such as thematic data specific to the relevant area and/or hazard (for instance, flooded areas and nursing homes) and real-time specific data (such as visualization and real-time tracking of resources) are important COP structures. This information could be pre-implemented in the GIS and thus facilitate structures for collaborative teamwork, such as mutual performance monitoring and backup behavior (Salas et al., 2005). An example is the possibility of inserting operational information that indicates possible hazards, such as the location of fires, safe zones, and "flags." For developing such structures, the pre-implementation of important agency-specific and common information needs and a structure for information sharing between the different IS that constitutes the COP (see Appendix F) becomes

crucial for effective decision-making and collaboration. This dissertation project contributes with common information categories related to extreme weather events and a discussion on how to facilitate this by using a window report structure.

As mentioned in the literature review, a high amount of research points to insufficient relevant information as the main decision-making challenge in the response phase of EM (e.g., Bharosa et al., 2009; Van den Homberg et al., 2018). Therefore, an important part of the solution is novel information sources included in a COP. Correspondingly, several of the informants in this dissertation project emphasized the importance of incorporating sources of new information (both from the incident scene and other EMOs) in the existing workflows and decision-making processes (Article #5). These are factors that constitute an environmental analysis and determination of emergency priorities, which are among the core factors for decision-making in the response phase of EM. This dissertation project demonstrates, by using live video as an example, that new information sources must be incorporated into the EMOs' routines and operative information management systems. However, considering the developments in technology, and the possibilities to utilize it in EM response, the work processes occasionally need to be updated or adjusted in line with the possibilities inherent in the new technology.

Article #5 contributes insight into how a live video system can be used to collect data from the incident scene and how this can be integrated into the existing workflows in a CCC. The article demonstrates that it is important to adjust the existing workflows and reflections on what scenarios the novel systems and information sources can contribute to. These factors are important for avoiding delays, information overload, and limited attention to other critical cues or elements. The results demonstrate that such visual real-time communication can enhance SA in multi-agency operations, especially in unclear situations. The possibility of sharing the same video stream between the EMOs – for example, as a part of the triple-alert routine (Appendix F) – is considered an opportunity for facilitating a common situational understanding. Because of the agency-specific information needs, one can assume that the possibility of assessing visual information is beneficial for an initial operation. In this way, agencies can simultaneously obtain the information that is important for them. This supports

previous research on using data visualization for common situational understanding (e.g., Redlich et al., 2017). What kind of IS constitutes the COP is, therefore, an important consideration when preparing the structure and representation factors of COP systems.

Based on the results of this dissertation project, a COP represents objective information and is a product based on preparation and a structured working methodology that involves shared knowledge across the three-tiered C2S. This knowledge consists of the EMOs`operational modes (including elements such as goals, resources, tasks, and the use of IS) and the pre-knowledge of common information requirements during the response phase of an emergency. The common information categories presented in this dissertation (Article #3) are shared SA elements that contribute to closing the gap constituted by heterogeneous information needs and different IS and provide information that covers several of the involved EMOs' information needs (i.e., team SA) (Endsely, 1995). The receiving stakeholders may, based on their professional standpoint and experiences, also be able to project a future status (Level 3 SA) based on the received information from the COP combined with the content of a communication structure (such as the window report or IERO structure). However, this is an individual process supported by the stakeholders' SA and mental models. Since a COP consists of factual information, it does not guarantee a common situational understanding, as the involved organizations with different tasks might emphasize the data that mostly concern themselves. Further, additional and more abstract information (such as implications and interpretations) must be negotiated through a trading zone to develop a common situational understanding.

7.3 Third element: Negotiating a common situational understanding

The information included in a COP can enable the individual stakeholders to develop all three SA levels. However, in multi-organizational EM, the individuals' SA is insufficient for developing a common situational understanding. The development of a common situational understanding concerns additional and more abstract information – for instance, the human capacity to share a diagnosis of unexpected behaviors and problems quickly and accurately (Arciszewski and De Greef, 2011). For this to be made possible, the

results of this dissertation project support the idea of a trading zone for negotiation (Boersma et al., 2012) as being a necessary factor to consider during emergency operations.

According to the results of this dissertation project, the COP provides an objective representation of the operational and situational information of an emergency and thus functions as a baseline assessment for a common situational understanding. This view adds to existing research on COP and common situational understanding by specifying the differences between the two concepts as presented in Article #4.

In time-critical situations, verbal message exchanges can enable stakeholders to negotiate the contents of a COP, including their understanding of this; make decisions; and plan for actions in a trading zone. The use of IS, such as radio communication devices, for facilitating such negotiation demonstrated in this dissertation project contributes to the trading zone concept by suggesting structured verbal communication in predefined communication paths across the three-tiered C2S (Article #6). Such verbal message exchange can contribute to the sharing of information that cannot be included in the COP (i.e., semantic and pragmatic information) or time-critical situation reports and updates in the trading zone. Examples of information elements that cannot be included in a COP are presented in Article #6. Further, the results of this dissertation project also point to the fact that negotiation plays an important role in clarifying misunderstandings and finding the best solutions for addressing different situations (Articles #4 and #6). Also, since the organizations in this dissertation project use different structures and systems for decision-making and actions, the negotiation process with colleagues is an important feature, and the trading zones provide the opportunity to efficiently exchange relevant messages. Even if free information exchange between different stakeholders seems to be necessary in time-critical and changing environments (Turoff et al., 2014), one must also consider information overload as a side effect. Considering this, predefined sharing structures for verbal message exchanges (such as the IERO structure and window reports) can facilitate information sharing in the format of situation reports and updates that include common information (Level 1 SA), comprehension of the information (Level 2 SA), and predictions of future status (Level 3 SA). Further, these structures must facilitate the sharing of

interpretations and negotiation of different interests between stakeholders because this will contribute to combining different perspectives and provide collective sensemaking. Nevertheless, the stakeholders must not be entirely tied up to such structures. Emergencies are unpredictable and require spontaneous time-critical information sharing and negotiations based on new incidents and changing environments. Thus, the stakeholders must go back and forth between the information provided by the COP and the message exchange in the trading zone. By following this, the stakeholders can develop a common situational understanding.

Article #1 in this dissertation investigated a real-time message exchange in a radio network during a full-scale multi-organizational exercise. The results document what kind of information categories the different stakeholders shared during the different phases of the emergency response (figure 11).

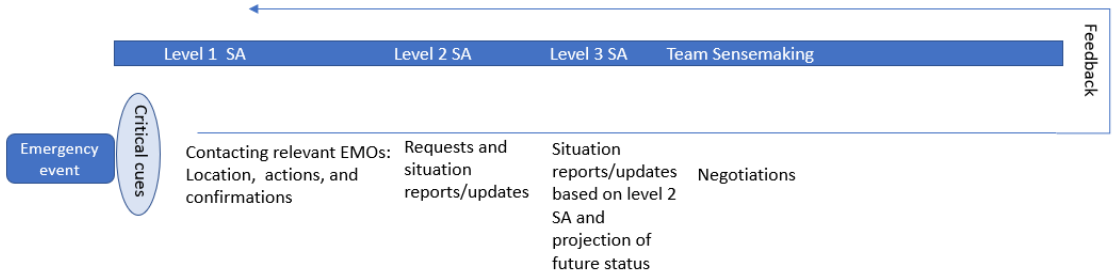

Figure 11: Information categories shared during the emergency response

These results contribute to the existing literature by defining the information categories in the message exchange during an emergency operation and hence suggest how to facilitate information sharing (both in a COP and verbally), as the information categories provide different SA levels.

The process of developing a common situational understanding is related to collective sensemaking, as the stakeholders must determine what is going on by creating an order of the information based on their perspectives and interpretations (influenced by their institutional background). Collective sensemaking describes how stakeholders are making sense throughout the whole situation from the beginning to the aftermath and how they assess the situation

itself. This emphasizes the importance of SMM, a COP, and standardized structures for communication and negotiation.

7.4 Decision-making and use of procedures in the three-tiered C2S

It is impossible to achieve complete SA and common situational understanding due to human cognitive capacity limitations. First of all, SA is an individual knowledge state that combines new information with existing knowledge in the working memory, as well as in the mental models that exist in the long-term memory (Salmon et al., 2007). A mental model then gives rise to what kind of plans and actions the person will select for a specific scenario. This is the foundation for human decision-making and shows how a stakeholder uses their experiences, professional background, and SA to make decisions. This section aims to present the findings related to decision-making and the use of procedures during EM across the three-tiered C2S and discuss the findings related to the literature on decision-making (section 4.2). This section then suggests how the different levels in the three-tiered C2S can establish procedures for supporting decision-making based on the perspectives and conditions for intuitive expertise included in the HB view and the RPD model.

The informants in this dissertation project explained how procedures support decision-making during the working process, and the results demonstrate how strategic, tactical, and operational C2S utilize procedures differently. This can be explained by the level of expertise of stakeholders related to a specific domain, the time spent on training (i.e., training that enhances the development of mental models), and the time perspective for the decision-making process.

The informants in the *operational C2S* (i.e., first responders at the emergency site) seldom use explicit procedures for making decisions. However, they have procedures available digitally on their smartphones or tablets, which enable quick searches based on cues typed into the application. This is typically used when they must respond to a nonfamiliar situation, and one of the responders reads the procedure on the way to the incident scene while another colleague is driving. Some stakeholders point to the time limit for reviewing procedures – for example, in larger cities with a high population density, the response time (i.e., the time spent driving to the emergency site) for the resources is reduced.

Stakeholders can also call the tactical C2S (often the CCC) for updates on procedures. Experts on, for example, critical infrastructure (e.g., the power grid and road network) make decisions based on their expertise.

In the *tactical C2S*, the informants across the EMOs have a quite fragmented set of procedures. Some have checklists (the police and fire CCCs), some have more algorithm-based procedures (the health CCC), and some have action cards related to specific scenarios (e.g., the municipalities and coastal administration). The companies responsible for critical infrastructure have alert lists for further contact with experts in different domains. The police, fire, and health CCCs have the triple-alert routine as a collaboration procedure that includes nine scenarios and guides the collaborative DM across the CCCs (see the description in Article #5).

The *strategic C2S* must make decisions based on both expertise and policy; therefore, their procedures consist of strategic plans and alert lists for contacting experts related to different domains. They make strategic long-term decisions and must be one step ahead.

The discussion between Kahnemann and Klein (2009) (section 4.2.) is relevant when discussing the use of procedures in the three-tiered C2S. While Klein (1993) advocates for expert intuitions (NDM) in the RPD model, Kahnemann (2011) supports the HB view. The results of this dissertation project indicate that both views represent important considerations for procedures supporting decision-making, related to which level of the C2S is in focus. Thus, one can argue that both Kahnemann's and Klein's perspectives and conditions for intuitive expertise are relevant in EM. However, there are several reasons why one should be skeptical of expert judgments – for example, extensive self-esteem and subjective confidence, the use of false information for restricting memories, and the requisite memory trap. Kahnemann and Klein (2009) suggest that it is possible to facilitate conditions for qualified intuitions and expert judgments through environments of sufficient regularity that provide valid cues to the nature of the situation and an adequate opportunity to learn through training. The cues must be (in principle) specifiable so that the expert's System 1 can utilize them, even if the individual's System 2 does not know what they are. In this way, an expert is guided by valid cues in the environment because of different

experiences. Therefore, an important notion is that expertise is not one skill; it is a collection of several skills. A stakeholder may therefore be an expert in some situations and not so much in others (Kahnemann, 2011).

Reflecting this view to EM stakeholders, one can suggest that stakeholders specialized in some limited areas (for example, first responders) are experts and can therefore make decisions based on well-developed mental models (i.e., expert intuitions). Since these stakeholders must work together in time-critical environments without access to collaborating procedures (or hardly any procedures at all), they can, by training the right way, develop SMM that enable them to collaborate efficiently. Stakeholders in the operational C2S can thus make successful decisions based on the RPD model. However, they must have the opportunity to review procedures based on the HB view (i.e., the stakeholders are guided by cues and guidelines in the procedures) if the situation they are facing is extremely complex and unfamiliar, which decreases their level of expertise and increases the risk of biases.

In the tactical C2S, the time perspective is also an issue; however, the stakeholders do not make decisions based on physical impressions, which limits the possibility of collecting valid cues to the different situations. Although the use of live video for information collection (section 6.5, Article #5) increases in CCCs (fire and health CCCs) and provides emergency dispatchers with a visual impression, the results demonstrate that the time pressure and complexity of the dispatchers' tasks affect when the video system is used. The informants regarded the system only as an additional feature that can be used if the situation is unclear and the time allows it. These stakeholders often simultaneously operate with multiple scenarios that are stressful, and many of the scenarios might not be so familiar when presented. Their expertise will allow them to make expert decisions, but the risk of biases seems to be higher in this C2S because they operate with limited SA. These stakeholders operate manly using IS, which makes them vulnerable to SA demons as well (Salotti and Suhir, 2019). The stakeholders can, in time-critical situations, make decisions based on the RPD model; however, procedures based on algorithms such as the triple-alert routine must be available in most of the scenarios.

In the strategic C2S, the majority of the stakeholders do not handle crises on a daily basis as their main task. This limits the criteria for making them experts (i.e., sufficient regularity and learning through frequent training/skill drilling). These stakeholders are not directly involved in the EM (e.g., their functions are supportive), and they use IS mainly for communication and collaboration. They are thus even more vulnerable to SA demons than the stakeholders in the tactical C2S because of the limited use of data collection and monitoring systems. Further, stakeholders at the strategic level have a less detailed SA and, therefore, decreased opportunities to assess critical cues. These stakeholders should therefore always base their decisions on plans and procedures based on algorithms or guidelines combined with expert opinions (i.e., the HB view).

Figure 12 sums up how the different levels in the three-tiered C2S can establish procedures supporting decision-making based on the perspectives and conditions for intuitive expertise included in the HB view and RPD model. Recall that most decisions are based on System 1 because it saves energy and does not demand extensive mental effort (section 4.2.1). System 1 is used unconsciously; thus, the first decision will be made as an RPD (as defined in the RPD model). Using System 1 to make decisions is based on previous experiences and is thus prone to errors. The levels in the three-tiered C2S should therefore support their procedures using the HB view to varying degrees.

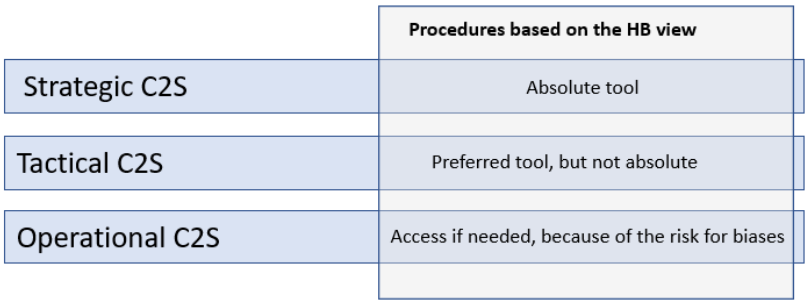

Figure 12: The relationship between the heuristics and biases view, the recognition-primed decision model and procedures

8 Conclusion

This chapter summarizes the findings as a whole. Further, the practical implications and theoretical contributions are presented. Finally, the chapter addresses the study's limitations and implications for further research.

8.1 Summary of findings

In this dissertation project, I have studied different aspects of how EMOs can build a COP and develop common situational understanding in the response to complex emergencies. The motivation for exploring this phenomenon derived from challenges in EM practice (problem-driven study), as both evaluations after real events and existing research demonstrate several issues related to collaboration and information sharing among emergency organizations.

The phenomenon has been investigated through one main RQ and four sub questions. SQ1 was defined to explore and understand the EMOs' work processes and how they can enhance their SA and collaboration practices (for example, building a COP) through exercises. With SQ2, I identify and provide knowledge on the EMOs' mutual information requirements for supporting their collaboration processes. SQ3 has been formulated to elaborate on findings related to the mutual information requirements based on SQ2, and further provide a clearer distinction between the concepts of COP and common situational understanding when it comes to practice. SQ4 addresses how IS can be utilized to support the collaboration practices for building a COP and common situational understanding during the response to complex emergencies. This SQ also addresses the need for incorporating the IS in the EMOs`complex working processes.

The philosophical grounding for this study was constructivism as the ontological perspective and interpretivism as the epistemological assumption. The empirical basis is qualitative interviews of relevant stakeholders in EMOs included in the three-tiered C2S, analysis of audio logs, and observations of multi-organizational exercises. On two occasions, a survey was used for data collection. A literature review was conducted for each stage of the research process to answer the different SQs.

The overall RQ addressed in this dissertation project is stated as follows:

How can EMOs establish a COP and further achieve a common situational understanding in complex multi-organizational operations?

The published articles contribute to answering one or more SQs, as presented in table 21. However, as explained in Chapter 5, additional results and published material that are not included in the dissertation articles also contribute to answering the main RQ.

The results of my empirical studies, combined with the literature reviews conducted at the various project phases, show that common situational understanding is based on a process that includes training for the development of shared mental models, pre-definition of common information needs, a COP, and facilitating negotiations and communication structures in a trading zone (figure 10). Different IS solutions are being used by emergency management stakeholders to support SA, flows of information, communication, and collaboration. However, SA is not created by the technology alone, but reflects the state of the user of the system and, therefore, many other factors will influence the stakeholder´s conception of the situation. It is important to consider cognitive factors at all stages because the stakeholders are humans that operate and make decisions in complex and dynamic environments. Frequent exercises with a focus on "drill the skill" will enhance information sharing practices and develop SMM. Using evaluation methods, such as a self-led AAR approach, combined with an objective and better fact-based evaluation process will increase the ability of both emergency stakeholders and researchers to reconstruct an exercise for retrospective analysis. The methodology for evaluating the real-time verbal communication between the stakeholders during an exercise (see Article #1 and chapter 6.1) shows how it is possible to utilize audio logs to enable the stakeholders to avoid the requisite memory trap (Bhatt and Gusgen, 2012; Gjøsæter et al., 2019). Using this type of evaluation method contributes to meeting the need for retrospective analysis. The content of the audio log messages (figure 11) documents what information categories are exchanged during the phases of an emergency operation, which function as categories for evaluating the COP.

There is a need to pre-define information categories so that the stakeholders can both prepare for and be aware of each other's information needs for building a COP in complex emergency events. The results of this dissertation project have identified eight categories of common information requirements that are necessary for building a COP when several EMOs collaborate to tackle extreme weather scenarios (see Article #3 and chapter 6.3). Such situational and operational information can be characterized as evidence of what happens, where it happens, and what is done by whom. Special attention to critical information needs, not merely at the organizational level but at the multi-organizational level as well, supports the collaboration and the response activities can be more effective. The identified common information requirements also apply to other complex emergencies than the studied extreme weather scenarios. *Location* includes information on the scope and exact position of the important locations. An important finding here is that the organizations` lack of access to the same GIS interface costs the involved stakeholders a considerable amount of time explaining locations to the collaborative organizations. Thus, shared access to a GIS is an important element of a COP. Further, *Critical infrastructure*, *Critical buildings, and Evacuation possibilities* are information requirements that should be included in a COP for providing important information during for example terror incidents. *Information on possible victims, Resources,* and *Situational development* might need to be negotiated and therefore needs to be shared verbally.

The COP is a result of preparation (predefined common information requirements and training for SMM), relevant IS (such as GIS, secure radio networks, live video streaming, and incident management systems, and a structured working methodology. The working methodology consists of how to share the relevant information, for example by using a window report and/or the IERO structure. The identification of common information requirements for different contexts is important for the future practice of developing a COP. The information could be pre-implemented in, for example, a GIS.

Procedures for cross-organizational collaboration are necessary for helping the stakeholders to involve the relevant organizations and also for guiding them into using the cognitive system 2 by introducing them to several decision alternatives.

In addition to sharing the factual information via a COP, it is necessary to quickly share information at the syntactic and pragmatic level, clear up misunderstandings, and provide crucial situation updates by communicating verbally to all relevant stakeholders. Verbal communication in common call groups using a secure radio network is identified as a key element in the actors' negotiation process for achieving common situational understanding. This study suggests the information elements that must be negotiated across the three-tiered C2S for collective sensemaking and common situational understanding using predefined communication paths (see Article #6).

Additional operational information, as well as new information collection systems and sharing practices, affects the working processes in such complex organizations as the EMOs. This is related to receiving information both from lay bystanders and collaborating organizations. Novel ways of information collection and information sharing, such as live video, can build on existing professional knowledge and enhance the stakeholders' SA. Several multi-organizational scenarios, for example, those implemented in the triple-alert routine, could benefit from such live video streaming and enhance the common situational understanding.

When managing complex emergencies, different stakeholders have access to different information. The distribution of critical information must not be dependent on a single type of communication. For building common situational understanding in complex events, both visual, textual, and verbal information is relevant because it requires bidirectional communication to clear up misunderstandings, share interpretations and implications, as well as the possibility for sharing factual information.

8.2 Theoretical contributions

IS research differs from other domains as it concerns the use of artifacts in human-machine systems (Gregor, 2006). IS research requires a wider view than the technological aspect; hence, the relevant theoretical basis must link natural and social science and technological science. This interpretive study aims to gain a deeper insight into the phenomena investigated and not to generalize to populations (Orlikowski and Baroudi, 1991).

Walsham (1995a) identifies four types of generalizations from interpretive studies: development of concepts, generation of theory, drawing of specific implications, and contribution of rich insights. This dissertation project contributes rich insights and enhances the body of literature concerning the complex processes of multi-organizational EM. It also contributes to the further development of NPT in extending its application from the health domain to multi-organizational EM. The study provides four main conceptual contributions: First, the theory of SA is combined with several cognitive processes relating to multi-organizational EM. Second, it provides a clearer distinction between the concepts of COP and common situational understanding and proposes steps to move between these two stages. Third, it contributes with a methodology for a more objective evaluation after multi-organizational exercises to avoid post hoc rationalization. Fourth, the application of NPT to the EM domain provides a deeper understanding of the normalization process of novel use of IS across organizations. These theoretical contributions are elaborated below.

This dissertation project provides more knowledge about the complex processes behind multi-organizational EM by combining the SA model (Endsley, 1995) with several elements: the importance of training and identifying common information needs for the development of SMM, collective sensemaking, and implementing the natural decision-making (NDM) and heuristics and biases (HB) views of decision-making. My awareness of the relevance of these concepts has gradually emerged through this project`s data collection and results, combined with the review of existing theoretical concepts. Firstly, the importance of training and the SMM concept became prominent both during evaluations of the full-scale exercises and by the results of the Mandal exercise. The interviews and the review of the audio logs after the Mandal exercise showed that the stakeholders enacted several elements of SMM after years of frequent training. This also applied to the use of the radio network and structured communication and information sharing. The SA model includes both the concepts of individual mental models and shared mental models because the mental models form the stakeholders` ability to direct attention to the important information elements. I argue that the training aspect is so important for developing SA that frequent small-scale training needs to be an integrated part of building mental models and developing SA and common situational understanding. The sensemaking concept includes a key perspective; the underlying assumption that sensemaking is

largely retrospective – and that the stakeholders, therefore, act first and then later try to explain their actions. Performing after-action reviews will thus strengthen the collective sensemaking and develop SMM.

The relevance of decision-making concepts (NDM and HB view) emerged during investigating the stakeholders` explanations of how they make decisions and reviewing the use of the triple alert routines.

Figure 13 presents a visualization of the theoretical perspectives and concepts combined in this dissertation.

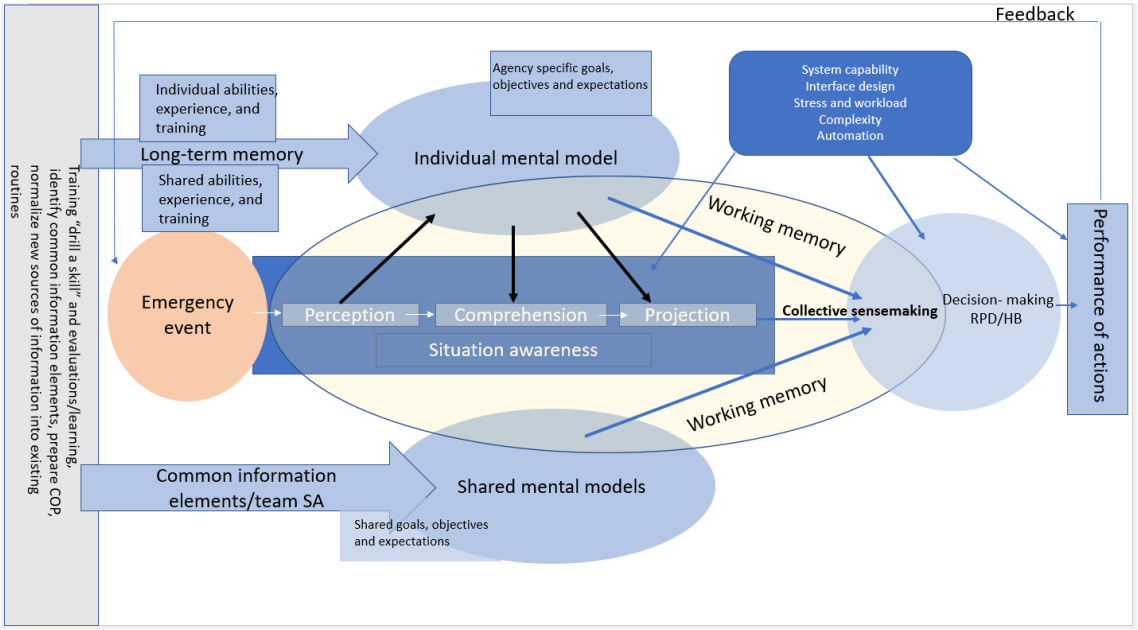

Figure 13: Combination of theoretical perspectives and concepts in the dissertation

Figure 13 illustrates how the training and evaluation perspective forms a basis for elements in the long-term memory such as individual abilities, experiences, and training both at an individual level and a team level. The training must involve the identification of common information elements at all levels (i.e., semantic, pragmatic, and syntactic) and the development of a COP. As shown in the Mandal exercise, by "drilling the skills" in elaborative rehearsals, this will develop SMM, which include shared goals, objectives, and expectations. The three SA levels (perception, comprehension, and projection) are the involved individuals' overall state of knowledge and combine existing knowledge and experience with the current situation. However, with working memory as well as

well-developed SMM, the involved stakeholders prepare for action by collective sensemaking (i.e., including stakeholders' experiences and training with the current situation – and the people they interact with). This enables them to make successful decisions for common goals based on their perspectives, roles, and prerequisites in the emergency response. The decisions can either be based on the RPD model or should be supported by procedures that include the HB view by introducing several options and information elements.

Based on practitioner perspectives on the concepts of COP and common situational understanding, a clearer distinction between the concepts is provided. The COP term is connected to an objective state of the operational information related to the emergency situation provided by different IS. In particular, various important visual information can be used to provide a higher level of SA related to the specific stages of the crisis operation. The COP comprises information at the syntactic level. Common situational understanding, however, is the stakeholders' common interpretation of the state of the environment, for example, the information provided in the COP. Verbal communication is the best way for a quick negotiation of the different understandings of the COP with the collaborating actors to plan for further actions. The distinction between the concepts provides an understanding of the steps in how to get from one to the other (Article #4).

Article #1 contributes a more objective evaluation method for avoiding post hoc rationalization by presenting a methodology for analyzing the development of COP and SA. The method consists of communication exchange categories that can be used for post hoc analysis of real-time communication related to establishing a COP in multi-organizational EM. This methodology can function as an important supplement to textual reports and retrospective interviews for future evaluations of both full-scale exercises and real events.

NPT is primarily used in healthcare settings (Sutton et al., 2018), while in this dissertation project the theory is applied to organizations beyond the healthcare domain. NPT can be seen as a mid-range theory because it is moderately abstract, has limited scope, and could lead to a testable hypothesis (Gregor, 2006). It is emphasized that there is a need for theory-driven approaches to new practices that require complex changes in clinical routines (Grol et al., 2007). It helps to

examine the workflows, technology in everyday use, and practices of embedding (Pope et al., 2013), which is a suitable focus for the phenomena investigated in this dissertation project.

8.3 Practical implications

The practical contribution of this dissertation project is the detailed insights provided by the data collection in the different phases. The results imply a strong need for improvement in the area of building common situational understanding in terms of using different IS for COP and information sharing. The project has identified eight information requirement categories that are necessary for building a COP when the first response agencies and municipalities tackle extreme weather scenarios. This facilitates the inclusion of a COP perspective, and developing a common GIS interface is advocated.

The project has identified some important functionalities for the IS to support information sharing, build a COP, and develop common situational understanding, where system interoperability across the EMOs appears as a key element for effectiveness. For example, interoperability between the EMOs` geographic information systems can save the stakeholders a considerable amount of time by not having to explain locations to collaborative organizations. Visible positions and lines in a GIS can improve strategic coordination between the actors involved. Further, an uncomplicated and straightforward system setup is crucial for not delaying the prompt reaction to incidents. The IS must be an integrated artifact into the information management systems, procedures, and working processes for preventing additional work operations. Another important functionality is to be able to route emergency calls, both verbal and visual (through video), between the EMOs for information sharing and providing the stakeholders the possibility of assessing the situation firsthand.

Using the IERO structure and/or window report serves as templates for which information categories need to be shared, and with whom, in different types of crises. The elements in the proposed framework (figure 10) can contribute with perspectives from different stakeholders across the three-tiered C2S when developing collaboration procedures and tools in practice. Such perspectives are

needed to help bridge the gap in collaboration processes between the different types of organizations and professionals who respond to complex emergencies.

The results from the audio log analysis and participation in exercises (such as the Mandal exercise) suggest frequent multi-organizational exercises that build on simple problem-centered scenarios and frequent elaborative rehearsals (i.e., “drill the skill” and facilitate the formation of memory by linking new information to what one already knows) in a safe environment using blended learning methods. The study also contributes with a methodology for post hoc analysis of real-time communication as an important objective-based supplement to AAR. Gaining the detailed information that has been exchanged will contribute to strengthening the post-event debriefing and evaluation by comparing the involved stakeholders' narratives to the actual communication during the event. Comparing the contents of the audio log from an exercise to the proposed categorization framework can provide a common discussion on important elements for a COP and the outcome of the interactions.

The audio logs and interviews also showed that stakeholders need to acquire new structures for negotiation and communication in order to decrease information overload and increase common situational understanding. To achieve this, predefined communication paths using a radio network must be planned and implemented between all relevant stakeholders across the three-tiered C2S.

Another practical contribution is the framework for how to get from a COP to a common situational understanding (figure 10). Practitioners can use this to gain an understanding of the interplay between the three elements and further how theoretical concepts such as the NDM and HB views in decision-making can contribute to the development of procedures. The contribution of this research is increased understanding, based on theoretical assumptions, of how practitioners work and their perspectives on improvements of practice and concepts such as COP and common situational understanding. The framework can be used as a tool to support the development of emergency plans in complex emergencies and facilitate the improvement of emergency response that entails communication patterns, the building of a COP, and the development of a common situational understanding.

8.4 Limitations and suggestions for future research

This section discusses the study's limitations and provides suggestions for future research.

The informants in this dissertation project are characterized as experts, and many of the informants in the qualitative interviews were chosen by their managers as highly qualified actors in their field. Their perspectives may thus not be representative of the views of more novice stakeholders. The informants from the exercises were not chosen by me, and they had different experiences and seniority. However, a systematic approach targeting different stakeholders related to the length of experience could be valuable for reflecting different views depending on seniority. Drawing on expert perspectives appears to be a valuable method for investigating this dissertation's RQ.

Qualitative approaches were employed in this project to analyze the data. The attempt was made to focus on the stakeholders' perspectives rather than measuring their performance, which could provide interesting aspects when discussing the use of different IS and procedures. The study has also focused on a subset of the several IS used in EMOs. Here, I considered it to be most purposeful to focus on the IS which are either new or mostly used by a majority of the stakeholders. Examples are the NPSN, live video streaming, and the use of GIS.

While the suggested structures for information sharing (i.e., the IERO structure [Article #6] and the information requirements in the window report [Article #3]) are based on suggestions from the interviews of practitioners, they have not been implemented into the information-sharing process and studied to determine whether they actually improve the information sharing processes. It is important to consider these contributions as suggestions for how practice can be improved.

The scenarios focused in this dissertation project are mainly limited to extreme weather events, but the framework is suggested to be generalized beyond such scenarios. Extreme weather events require efforts from EMOs beyond the first responders and the application of such scenarios can offer valuable insights into

emergencies that embeds the complexity of multi-organizational emergency management. However, specific results such as the common information requirements (Article #3) cannot be automatically transferred from one scenario to another because of the characteristics in different environments. For example, the working processes and information sharing practices might be different in scenarios such as terror attacks. Information requirements such as *location* can in these situations be different for several of the involved EMOs due to the danger of ongoing life-threatening violence (PLIVO). A greater focus on common information requirements in different scenarios could produce interesting findings that account more for emergencies such as PLIVO operations.

The EMOs have experienced several changes in recent years, where they increasingly have to collaborate and complement each other by performing tasks that are basically outside their area of responsibility. An example is the fire and rescue services that are often the first at an incident scene and must perform tasks such as healthcare or securing the area. Many challenges in societal security span across sectors, which makes the principle of cooperation and information sharing particularly important. Dissemination of information must be weighed against possible considerations of privacy and the duty of confidentiality. There are exceptions from such duties, for example, securing lives and protecting societal interests. However, there are undoubtedly situations where the lack of necessary information sharing results in poorer collaboration due to duties of confidentiality and security-graded information (Security Act § 5-2). This is an issue that should be focused in further research.

The different information sharing practices (e.g., the IERO structure and using a common call group for information sharing) suggested in this dissertation project (Article #6) provide interesting opportunities for further research. For example, by implementing the information-sharing practices in a full-scale multi-organizational exercise, one can determine whether they improve the information-sharing processes and contribute to the development of common situational understanding, and also investigate whether any barriers and challenges are associated with the implementation of such predefined structures.

Further, I posit that there is a need for empirical studies to assess the tactical C2S as a trading zone and the role of information managers at the operational level. It is also important to understand how these information managers can facilitate information sharing without becoming a critical single point of failure.

There is still a need for more research on the negotiation of different information elements between the C2S and on facilitating a structure for communication that supplements the factual information that is provided by the COP. This can be done by developing multi-organizational guidelines for verbal status reports in a common call group (see the NPSN in appendix F) that support the need for negotiation on the predefined categories of information elements.

Overall, this dissertation project has contributed to a holistic understanding of the information-sharing process for developing a common situational understanding in multi-organizational emergency events, including the human cognitive capacity of the stakeholders involved and the use of IS for decision support. The empirical data show that this process includes the development of SMM, pre-definition of common information needs, establishing a COP, and interpretation of the information through verbal negotiations. The findings from this study can thus serve as a basis for further research on improving multi-organizational response in complex emergency events.

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Appendices

Appendix A. Example from Audio log analysis

The following is an example from the analysis of the audio logs from the Norwegian Public Safety Network.
First, the audio tracks were transcribed in full. Then the messages were coded and classified into appropriate categories that described the content.
Examples:

Summary of messages:	**Information category:**
1. Have received a situation report in Sam Eyde*	New emergency event
2. Yes	Confirmation
3. Have you perceived the message?	Request for confirmation**
4. Received message	Confirmation
5. Join call group BAPS3	Action
5. The bus hijacked in Sam Eyde	Situation report
6. Repetition (of event description)	Common understanding/best practice***
7. Situation report from the event location	Situation report
8. How can fire services help?	Offer resources

*A town square in Arendal
**The receiving part did probably not perceive the first confirmation
*** Repetition of the received information is described in the regulations for NPSN as best practice.

Figure 1 shows the Excel spreadsheet for the first minutes of the emergency operation.

2	Using Timeline from BAPS3 files				
3	time	Origin of message	Destination	**Summary of message**	**Information Category**
4	XX 10:00	CCC 112	CCC 110	Have received a situation report in Sam Eyde	New Emergency Event
5	XX s 10:03	CCC 110	CCC112	Yes	Confirmat Kvittering
6	0,423808	CCC 110	ILKO	Have you heard the situation	Request for confirmation
7	0,423611	ILKO	CCC112	Received message	Confirmation
8	0,423611	ILKO	CCC 112	Join tale gruppe BAPS3	Action
9	0,423611	ILKO	CCC 110	The bus hijacked in Sam Eyde	situation report
10	0,423611	CCC 110	ILKO	Repetition of Event	common understanding
11	0,423611	ILKO	CCC112	Situation report from event location	Confirmation
12	0,423611	CCC 110	CCC 112	How can fire serices help?	Offer Resources
13	0,423611	CCC 112	CCC 110	Give ideas what things brann can help	Request for Information
14	0,423611	CCC 110	CCC 112	We will come back with more information	Action Plan
15	0,423611	CCC 113	CCC 112	AMK has joined BAPS 3	Action
16	0,423611	CCC 113	CCC 112	Do you need health resources?	Offer Resources
17		CCC 110	All	Join a wrong tale gruppe	Error

Figure 4: Spreadsheet

We then merged the categories that had similar content, and by this narrowed down 22 categories to 14 categories. An example is “location uncertainty” and “location clarification” that were merged into one category called “location”. The descriptions of the categories were specified Table 1 shows some examples.

Table 3 Categories

Category	**Description**
Confirmation	If (they) repeat or agree on the question such as "have you heard the event?"
Action Plan	Can include coordination plan, information plan, prediction of the situation
Action	Can include following an order, initiating action, and sending a request
Situation report	Can include information on victims, occupied resources (e.g., one has to wait), or can include updating information
Information Mismatch	Lack of common understanding of the situation. An example is when a fire crew searched in (the road cross name) while 112 and 113 knew that there was nothing there
Error	Distracting element (sound) human error, no harmful error

Appendix B. Interview guide (articles #3 and #4)

This interview guide is originally in Norwegian.

1. Introduction

- Present myself
- Explain the background of the study and purpose for the interview

This interview guide is a "to-do list" of topics I want to address, but if there are other subjects that are relevant to talk about, then we do that.

Research shows that our climate is getting warmer. One of the consequences is more and larger forest fires (uncontrolled fires in nature, which can claim human lives, destroy buildings and agricultural areas).

2. Informant background

- Name, profession, role

3. Experiences with professional development and exercises/evaluations

- Have you previously prepared yourself by consciously seeking knowledge that you did not already have concerning forest fires? This could be, for example, to be prepared for something you have not handled before? How?
- Do you have arenas for developing competence in handling large fires (or other natural events?) If so: which arenas? (how, when, why)
- How do exercises work in your organization? Give examples.
- How do you carry out the evaluation processes?
- How do you handle the findings after an evaluation? In what way are they implemented? Give examples.

4. Organizational goals/decision-making/procedures

Comments from the informants on the following goals:

- Limit human damage and save lives (protect residents)
- Limit that the crisis/situation escalates
- Limit damage to critical functions
- Inform residents
- Encourage the public to take action (self-preparedness)
- What information needs do you have to achieve these goals?
- What information needs do you have in extreme weather situations? (flood / storm / +)
- What kind of knowledge does this information provide you / what does it tell you? Can you give examples?
- What can you predict – i.e. what consequences can you understand from this information?
- What decisions do (did) you have to make in such a process?
- What influences your decisions?
- How do you use procedures in such processes, how are the procedures structured?

5. Information sharing

- Which organizations/individuals do you contact to meet your information needs (for example for achieving your goals)
- How often do you have to contact these people/organizations?
- Can you rank which ones you must contact first (the most important) and then the next (and so on)?
- Is there anything that might hamper this communication? (experiences, examples)
- Is there anything that might promote this communication? How can this be made even more effective?

6. Experience with technology use in the current organization, and thoughts about technology in the future

- To what extent is technology used in your work?
- What technical tools do you use to collect the information needed concerning your goals?
- What kind of map support is used, and how?
- Is there anything that might hamper this use? (experiences, examples)
- What (possibly) can promote the use?
- Is there something you think can be better? (do you miss any opportunities?)
- How do you envision future emergency operations concerning technology use?
- Any expectations of what technology can do in the future?
- Do you feel that you have satisfactory training? (when the accident happens - do you feel comfortable with the use of the technology?)
- Are there any technology tools that you have not mentioned?

7. Developing a common situational understanding

- Do you know the other organizations' information needs?
- Can you specify these needs? (What do you think they need and why?) Give examples, experiences.
- How is the information shared? (both using human and technical resources)
- Do you have any procedures for collaboration? If yes, can you describe these?
- Have you experienced any problems related to different use of terminology in collaboration with other EMOs? Give examples.
- How do you perceive/understand the terms 'common operational picture' and 'common situational understanding'?
- How is, in your opinion, a common operational picture established and shared?
  - How can this be done in the future?
  - How can common operational pictures be shared so that those who need them are up to date?
- How is, in your opinion, a common situational understanding established and shared?
  - How can this be done in the future?
  - How can situational understanding be shared so that those who need this are up to date?
- What are your experiences of achieving a common operational picture? Give examples.
- What are your experiences of achieving a common situational understanding? Give examples.

8. Closure

- Do you have anything to add?
- Thank you for participating

Appendix C. Key elements in the interview guides related to the thesis articles

Article #	Interview guide elements
Article #2	- Experience when receiving the SMS during the exercise, request for suggestions for improvements/changes for future surveys.
Articles #3 and #4	- Professional background - Exercises, evaluations, and arenas for professional development - Information needs/information sharing processes - Decision-making processes - Technological tools/information systems - Building SA, COP, and common situational understanding - Organizational structures and work processes behind the use and development of NPSN - Structures and processes supporting the use and development of GIS used by first-responders
Article #5	- Professional background - Context - Questions organized by the NPT elements
Article #6	- Professional background - Information sharing, and collaboration. - Information needs - Communication in NPSN - Questions regarding information exchanges/sequences - Decision-making processes - Use of procedures - Experiences and thoughts about the organizational structures and work processes behind the use of NPSN.

Appendix D. Survey 1: Information requirements

This Appendix presents the questions used in the survey for article #3: Identifying information requirements for improving the common operational picture in multi-agency operations.
As a basis for the following questions, a general description of each extreme weather scenario (storm and flood) was presented.

What information is important for your organization to have access to/receive in a storm scenario? Please specify critical information elements:

What information is important for your organization to have access to/receive in a flood scenario? Please specify critical information elements:

When managing emergencies involving victims/ injured victims, what can the followings terms mean, and when would you use them?
(These terms have been translated from Norwegian (in parenthesis), but do not necessarily have the same meaning in English. This data was therefore not used in further publications)

- Person not awake (ikke våken person)
- The person is not possible to wake up (ikke vekkbar person)
- Unconscious (bevisstløs)
- Dead (død)
- MORS (an acronym for the Latin term for dead)
- The person does not respond (ikke kontaktbar)
- Drowned (druknet)
- Not breathing (puster ikke)
- Lifeless (livløs)

Appendix E. Example of data analysis (article #3)

This Appendix describes the data analysis approach used for article #3 *Identifying information requirements for improving the common operational picture.*

The data collection for this article consisted of nine qualitative interviews and a survey with six respondents from organizations beyond the first responders. Altogether data from 8 different organizations were represented. Table 1 presents an example of the coding process.

First cycle coding: I coded the transcriptions and survey responses into nodes. I started with four broad nodes: Organizations, Scenarios, Goals, and Information sharing.

Further, the organizations were coded into three different child nodes: first responders, municipalities, and supporting organizations such as the Civil Defence. The scenarios were coded into *forest fire*, *storm*, and *flood*. Information sharing was coded into procedures, challenges, and experiences.

The *organization* nodes were revised, and information needs were put in child nodes under each organization.
Second cycle coding: This consisted of the following three interations:

- 1st iteration: The information needs were coded into different scenarios (for example storm).
- 2nd iteration: The information needs were coded into information need categories (for example location). I analyzed the text once more and created information need categories across the different scenarios based on similarities and differences in the information needs. For example, location and resources are important for all scenarios, i.e. some of the text was related to several categories. The nodes were renamed or created accordingly. A total of 11 information need categories were developed. See table 1 for an example.
- 3rd iteration: The information need categories were reviewed and grouped into common information requirements and connected to the involved organizations. See table 2 for how the information categories were spread between the different organizations. The colors represent common information categories across the organizations. For example, *location* is common for all organizations, while organizations 12 and 13 have *area of fire*, *critical infrastructure*, *evacuation possibilities*, *fire development*, and *capability to solve tasks* as additional common categories.

Table 4: Example of the coding process

Quotation	Nodes First Cycle Parent Node: Organization	Nodes Second Cycle 1st iteration Parent Node: Scenario	Nodes/Categories Second Cycle 2nd iteration Parent Node: Information Category
"Updated weather forecasts and mapped information about the situation are highly desirable".	Child Node: Storm scenario Child Node: County Governor	Child Node: Information Need	Child Node: Location Child Node: Weather forecast
"It would have been good if we had access to the others` operative units in our GIS, it is very often that another agency is on-site before us, then I could see exactly where they are and mark it in my map and send the position to my units. And the other way around"	Child Node: All scenarios Child Node: Police Services	Child Node: Information Need	Child Node: Location Child Node: Resources
"Location is critical information. It is important where the flood is, thinking especially about whether there are buildings or road networks that are affected. This also affects what resources we must alert and what other agencies that can provide support"	Child Node: Flood Child Node: Fire and Rescue Services	Child Node: Information Need	Child Node: Location Child Node: Critical Infrastructure

Table 2: How the information requirement categories were spread between the different organizations

	Location	Area of fire	Critical infrastructure	Information on possible victims	Weather trend	Evacuation possibilities	Fire development	Critical functions	Buildings	Resources	Capability to solve tasks
Organization10	x	x	x	x	x		x				
Organization9	x	x	x	x	x		x				
Organization1	x	x	x	x	x	x					
Organization11	x	x	x	x	x			x	x		
Organization8	x	x	x	x	x			x	x		
Organization7	x	x	x	x	x						
Organization12	x	x	x			x	x				x
Organization13	x	x	x			x	x				x
Organization6	x		x	x							
Organization3	x		x		x						
Organization5	x		x				x			x	
Organization4	x				x		x			x	
Organization2	x		x				x	x	x	x	x
Organization15	x					x	x	x	x	x	x
Organization14	x			x	x	x	x	x	x	x	x

Appendix F. IS systems used in EMOs in Norway

IS for supporting communication and information sharing between different emergency organizations

This appendix briefly summarizes current practice with IS support for communication and information sharing between the EMOs in Norway. Several ICT-supported systems related to various activities and phases in response operations are in use; however, there is limited integration between the systems, which results in a general lack of tools for sharing information between the organizations (Munkvold et al., 2019).

CIM (crisis management system)

CIM (https://cim.f24.com/en/cim-en/) is a text-based crisis management system being used by many Norwegian municipalities, county governors, the government's crisis support unit of all ministries, several directorates, hospitals, the Civil Defence, the police, and several NGOs. The system consists of modules that provide support for basic activities in EM, such as action cards, log modules, email, and alert/notification. However, CIM use varies considerably, regardless of good accessibility and training (Munkvold and Meum, 2013). The sharing of reports between different CIM installations is an identified need for improvement (Munkvold et al., 2019), considering the information-sharing aspect is not fully emphasized.

The Norwegian Public Safety Network

Verbal communication in EM practice has focused on the interoperability of mechanical devices, such as handheld data devices, radios, and landline and satellite telephone networks (Comfort, 2007). One of the core technologies is radio communication devices, and such handheld radios are commonly used for interactive communication between different stakeholders during emergency response. Different channels in the networks are distributed among the stakeholders, depending on their roles and information needs (Waring et al., 2020). All stakeholders in first responder organizations are equipped with one or more radio handsets, both on themselves and in their vehicles, for collaborative communication, both internal and cross-organizational.

Handheld radio networks are frequently used for interactive communication between different stakeholders in crisis operations. The Norwegian Public Safety Network (NPSN) is the national digital radio network for EMOs in Norway. It is a separate radio network covering the whole country, and it was implemented in 2015 and replaced all other verbal communication systems in the first responder agencies. Organizations other than first responder agencies have since been connected to the NPSN, including NGOs, many municipalities, county governors, private critical infrastructure organizations, and several other public resources. However, the adoption and usage of the NPSN in these organizations varies (Steen-Tveit and Munkvold, 2021).

The terminals are traced by the Global Positioning System. One of the most important functions in the NPSN for multi-organizational communication is the ability to set up different call groups or “digital rooms.” It is possible to set up several call groups during an emergency operation, both agency-specific and cross-organizational, and stakeholders use different channels, depending on their role and information needs. Communication in the NPSN is regulated by a set of common expressions (e.g., “understood,” “repeat,” and “received”) to avoid misunderstandings, reduce the length of messages, and decrease disturbances (DSB, 2018).

The triple-alert routine

Information sharing between the first responder organizations (i.e., police, health, and fire services) in some specific scenarios is facilitated by the national triple-alert routine (Norwegian Directorate for Health, 2019). The triple-alert routine consists of a tool for inquiry and action covering nine scenarios (bomb threat, fire in a building, acute pollution, tunnel accident, ongoing life-threatening violence, a person in the water, accident at sea, avalanche, and traffic accident). The routine describes when and how an alert among first responders should be initiated and implemented. The routine aims to secure simultaneous notification of first responders and mobilization of required resources, provide equal information for all at the same time, and allow the involved dispatchers to ask the lay bystanders questions and provide guidance. The tool consists of PDF documents available in the CCCs’ agency-specific operative IS. (See Article #4 for an elaboration of the triple-alert routine.)

Appendix G. Research publications

#	Article
1	Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *Using audio logs for analyzing the development of a common operational picture in multi-agency emergency response*. In Proceedings of the 53rd Hawaii International Conference on System Sciences, Maui, HI (USA).
2	Steen-Tveit, K. (2020). *Identifying information requirements for improving the common operational picture in multi-agency operations*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management Conference, Virginia Tech, Blacksburg, Virginia (USA).
3	Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *SMS-based real-time data collection for evaluation of situational awareness and common operational picture: Lessons learned from a field exercise*. In Proceedings of the 17th International Conference on Information Systems for Crisis Response and Management, Virginia Tech, Blacksburg, Virginia (USA).
4	Steen-Tveit, K., & Munkvold, B. E. (2021). From common operational picture to common situational understanding: An analysis based on practitioner perspectives. *Safety Science, 142*, Article 105381.
5	Steen-Tveit, K. (2022). *Using a public safety radio network for information negotiation between the three-tiered command and control structure*. In Proceedings of the 55th Hawaii International Conference on System Sciences (Virtual Conference).
6	Steen-Tveit, K., Munkvold, B. E., & Radianti, J. (2021). Using live video for communication between lay bystanders and emergency dispatchers in command and control centers. *International Journal of Emergency Management*. Vol. 17, No. 2, 154-176.

Using Audio-Logs for Analyzing the Development of a Common Operational Picture in Multi-agency Emergency Response

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Abstract

Multi-agency emergency response requires effective communication and collaboration for building and maintaining a common operational picture. Full-scale exercises are shown to be effective for learning, and for training the collaborative skills needed. This paper presents a methodology for the analysis of real-time communication for building the common operational picture, using audio-logs. The analysis of the audio-logs provides insights for both practitioners and researchers in the emergency management domain concerning the dynamics of inter-agency collaboration and information exchanges when responding to emergencies. Coding and categorizing of audio-log-based information exchanges among multi-agency stakeholders were applied based on a full-scale emergency exercise on multiple terror actions. The results show that the methodology can contribute to analyzing the development of a common operational picture, supplementing existing methods for evaluation of full-scale emergency exercises and real events.

1. Introduction

In large scale emergency events involving multi-agency collaboration several factors need to be in place, i.e. common communication tools, the establishment of a common operational picture (COP), mutual trust and respect, as well as awareness about own and other Emergency Management Services' (EMS) responsibilities and tasks. To make expedient use of those factors, it is important that the emergency stakeholders possess the knowledge of the systems and capabilities to use them to solve the tasks [1]. Yet, without the key information concerning the situation, cooperation is not enough to make a response operation more efficient [2]. Such operations typically deal with heterogeneous information needs, processes/ structures, goals, resources, technology and other features within the involved organizations [3]. Despite these heterogeneities, the key goal for all actors is to collaborate to save lives and limit damage.

Worldwide, mass causality incidents have a huge impact on communities, both in terms of human suffering and the economy. One example is the terror attacks in Norway on 22nd of July 2011, where 77 people, mostly very young, were killed and 260 people were injured in two planned attacks. The commission-report concluded that there were several blameworthy conditions and a significant need for changes. For instance, the report stated that some of the failures were due to impaired ability to recognize risk and that learning from exercises had been deficient, furthermore, the establishment of situational awareness (SA) and a COP during the response operation was insufficient [4]. Learning from previous decisions, actions and incidents must be practiced and evaluated through full-scale regional exercises to enhance the EMS' capabilities to handle mass causality incident operations [5].

Evaluation is a method for generating new knowledge and understanding in a certain setting, and by utilizing the results of the evaluation, the consequences can be changed in the affected organizations [6] As Weiss [7] states: «the overall aim of evaluations is to assist people and organizations to improve their plans, policies and practices». In multi-agency emergency management, the different involved actors are aiming to achieve a collective perception, but they are likely to transfer their own vision to the situation, based on their own professional standpoint [8]. Therefore, in an exercise involving several decision-makers, effective evaluation is an issue because different decision-makers operate with different understanding and knowledge about the situation [9]. This reflects the difficulty of objective evaluation of full-scale exercises [10] and the need for an efficient method for evaluation is essential to be able to defend the resource-and economic aspect of large exercises. The visualization of information in most evaluations relies on textual sources (such as reports) and interviews. The lack of real-time communication makes it difficult to gain the detailed information being

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978-0-9981331-3-3

exchanged, and access to this material will contribute to strengthen the evaluation`s results.

This paper extending previous findings [11], and aims to provide an analysis methodology for evaluating the COP established during a full-scale exercise, through post hoc analysis of the inter-agency communication using audio-logs. One of the advantages of this proposed approach is that the individual actor`s narrative (which is likely to be affected by their own view) can be compared to the actual communication during the event, to inform the post even debriefing. Thus, the method can provide an important contribution to existing evaluation methods. This approach offers a foundation for common discussion on important features and the outcome of the interactions. Moreover, the proposed categorization framework of the exchanged information provides the opportunity to evaluate the COP.

To demonstrate the usefulness of the approach, we conducted a temporal analysis of a full-scale exercise involving a multiple terror attack scenario. The analysis shows the changes in the multi-agency interactions and information being exchanged from time to time, reflecting the communication patterns, interactions and the importance of particular communications in different stages of the event. By investigating communication patterns and bottlenecks, the potential for improvement is possible [12].

2. Theoretical Framework

Situational Awareness: Disaster management is an active process over time, which gradually changes as the situation develops, and the signals change [13]. Disaster response systems must be able to handle the complexity of the emergency environment and include the fact that a variety of agencies will be involved in making complex decisions during the operation [14].

During these emergency operations, situational awareness (SA) plays a critical role due to performance and error prevention [15]. Therefore, it is necessary to establish SA during emergency management. The theory of SA is the foundation for a large number of studies on dynamic human decision-making in several domains [e.g. 16, 17-19]. With evolving technology support humans are able to act more effectively in decision-making when operating in dynamic systems [20]. SA in multi-agency operations includes complex cognitive components. While analysis of the audio-log from the response operation does not cover the actors' cognitive processes, the communication can reveal the state of SA in different stages of the operation. Moreover, SA is an important component for all actors involved for both creating and maintaining a COP (see figure 1). The SA theory is used by a number of other studies, for example as a framework for defining emergency stages by taking the available information into account [21] and how individuals develop different levels of SA by conducting a SA requirements - and resource analysis [22].

Endsley [23] defines three different levels of SA:(1) perceiving the elements in the environment, (2) comprehending the current situation, and (3) projecting the future status of the situation. The first level is crucial for the actor to achieve SA because it involves the critical cues/information needs, and further, it forms the basis for the construction of the two next levels. The actors` achievement of SA level 2 and 3 consists of important information to share, for instance, level 2 is the foundation for actions, and level 3 for action planning. This is also related to the operation`s goals, and in multi-agency emergency operations, such as in mass causality incidents, the actors interact interdependently toward a common goal [15]. The involved agencies must collaborate to reach the shared goals, and the critical information should not been kept individually or internally in the agencies [24]. The case to be presented in this paper clearly demonstrates the importance of SA within the agencies for contributing to a COP among all the involved stakeholders (figure 1). Without a sufficient SA the contribution to a COP will be incomplete.

Common Operational Picture: Collaboration and coordination are crucial factors for success in crisis management [e.g. 3, 25, 26]. Several studies and retrospective analysis point to challenges related to coordination in multi-agency emergency management [27-31]. Information sharing is a significant component in the collaborating process and the reliability of the shared information is crucial in intensive operations [12]. There are several bottlenecks due to information sharing among multiple agencies in mass causality incidents, and a major reason seems to be the nature of the incident itself. Several studies point to the complexity, the dynamics and the unpredictable aspect

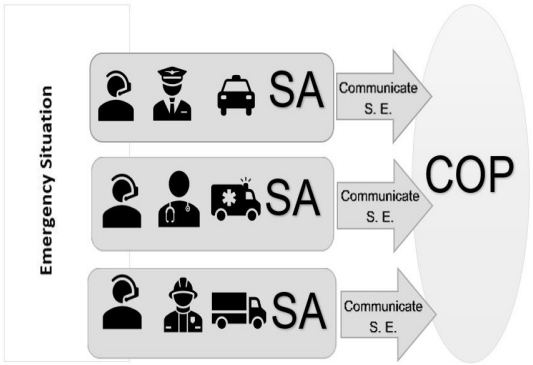

Figure 1 Agencies' SA and communication of shared elements (SE) to create a COP

of the environment [e.g. 20, 28] where collaboration needs to be unfolded.

The EMS needs a collection of relevant and verified information from different sources in the environment, and further to share this with the collaborating EMS. This includes both static and dynamic features of the environment [32], such as location, incident type, number of victims and threats.

The different agencies involved, representing different professional disciplines, will have some SA requirements that are internal and specific for the agency`s goal (see figure 1). However, in collaboration processes, many of their actions will be interdependent and they will have shared goals with the other involved agencies and thus shared SA requirements [15]. In communication that aims to achieve a COP, it is important for all the involved parties to understand information not only based on their own view but also what is crucial for the collaborating agencies.

This requires knowledge of each other's key elements, such as information needs, goals, expectations, responsibilities, resources, capabilities and procedures to achieve effective cooperation [33, 34]. Agencies with different tasks and goals might emphasize the data that mostly concern themselves [35], and absence of knowledge on these key elements can create an information overload or lack of information caused by ignorance or inability to determine necessary information to share [3].

In addition, the agencies utilize different terminologies [36]. Using different terminologies among the agencies addressing the same concepts and events can hinder the establishment of the COP. Heterogeneous awareness about different terms is a problem among emergency stakeholders [37]. An overview of crisis vocabularies are not always present, and when they are, they are distributed on diverse repositories designed differently and not harmonized across agencies [38]. It seems to be necessary with more coordination on terminology management [39] and the task-critical information must be exchanged by using harmonized terminology to build and maintain a COP.

The majority of the emergency management information systems facilitate only information sharing and do not emphasize the collaboration process [21]. The fact that the actors have different perceptions of information [40] implies that even if the information system provides a solid foundation for communication and information sharing, the lack of a standardized framework [21] for the collaboration process may result in ineffective processes for communication and cooperation.

The characteristics of a COP are relevant operational information across agencies [41]. Thus, to create a COP the communication must be structured to provide the involved agencies with accurate, timely and prompt information. The time aspect concerns several elements; sharing information in the least possible time because of the time-paced situation [42], sharing information in the different stages of the operation, and the continuous communication process for the involved actors` maintenance of a COP. Several studies underpin the importance of this upkeeping of a COP, and that it is a necessary component for the emergency operation to be effective [e.g. 41, 43, 44].

One must consider that complete SA is not possible in any emergency operation [40], but each agency involved will focus on collecting the task-oriented critical cues that provide the highest possible SA. Furthermore, in multi-agency operations, the individual agencies have a responsibility to create a COP together with the collaborative agencies. In addition to common SA elements, the COP is an accumulation of important information elements that are selected in different categories such as the different organizational actions, prognosis and perceptions [43].

The COP can be communicated by technology such as Geographical information systems (GIS), by providing a display of relevant operational information, such as positions, infrastructure and different resources using custom symbols [41]. Many EMS do not use the same GIS interface and only operate with tools supporting verbal communication in the collaboration process. Regardless, the communication of shared elements must be conducted in an appropriate way, using a standardized framework, definitions and common terminology [12] and symbols for successfully creating a COP (see figure 1).

Building a COP among multi-agencies is a skill that is focused as an important part of exercises in emergency management, and the inclusion of collaborative elements offer participants perceived learning [45]. Conducting a full-scale exercise is demanding both in terms of costs and resources required. Several factors need to be considered, such as the so-called "infallibility behavior" that refers to the participants` effort to do their absolute best to make an impression. Nevertheless, if a culture for learning exists, the participants are willing to reveal their weaknesses for the learning outcome`s sake [25]. The outcomes after emergency management exercises offer useful learning for the participants [46]. However, a study of three collaboration exercises involving the police, fire and ambulance services conducted in Sweden [47] revealed that the perceived impact on actual emergency work was moderate. The learning outcome did not include the collaborating EMS` way of communication and prioritizing, thus the collaboration elements in exercises should be strengthened. An important step in this would be a common understanding among the involved

agencies concerning basic concepts, structures and processes, thus knowing each other`s operational modes [12].

Based on the literature reviewed earlier, the following table summarizes important features for EMS to maintain a COP in complex emergency operations:

Table 1 Important features for a COP

1	Creation and maintenance of different levels of SA within the involved agencies.
2	Knowledge of each other`s operational modus, such as information needs, goals, capabilities, processes and resources.
3	Effective and time-specific communication of important static and dynamic environmental features, shared elements and common critical cues.
4	Harmonized terminology, both in vocabulary and software symbols.
5	Sharing useful comprehension of the current situation and actions/action planning important for the collaboration.
6	Follow a standardized framework for communication to avoid useless information and information overload.

3. Methodology

The empirical foundation for this paper is a case study of a full-scale regional exercise involving multiple terror incidents in southern Norway. The exercise was designed to train the cooperation among stakeholders in the field, but each involved EMS also had several internal sub-goals to train. Multiple qualitative methods were used, combining observation, audio-log analysis and validation with stakeholders after the exercise to clarify vague results. Using the audio-log as a methodology for post-hoc analysis allows the actual communication combined with the event timeline to reveal the "live image" of the communication among the collaborating stakeholders. This serves as an important supplement to traditional retrospective interviews and textual analysis, and it addresses the need for detailed information being exchanged during emergency operations.

3.1 Scenario

The exercise involved three interrelated incidents occurring almost simultaneously. The scenario was built on a terror attack where a single terrorist hijacked a bus with 20 student passengers at a school a few kilometers from the city center. The situation developed and required a multi-agency operation involving the police, fire and health services. The bus was not stopped and drove away from the event site. About 10 minutes later a traffic accident with an unknown number of human injuries occurred in a harbor intersection. The police Command and Control Centre (CCC) then issued a triple-alert (alerting all involved CCCs in a conference phone call) and provided a common update on the new incident for building a common operational picture.

Yet another incident was alerted after 5 minutes, from a public witness reporting that the hijacked bus had driven into a crowd attending an open concert by the waterfront of the city center. A large unknown number of people was injured both on land and in the water, creating a chaotic situation. The police CCC updated the fire and health services on the new incident and informed about the caller's perception of an intentional event (the act of terror). The police defined the situation as an ongoing life-threatening violence operation, which activates specific procedures for all agencies involved. Furthermore, this situation required the involvement of more organizations such as the Sea Rescue, the affected municipality, Volunteer organizations and the Civil Defence. An assembly place for injured and deceased was organized, and incident commanders for police, fire and health services were appointed. Evacuation of the area, the establishment of a next of kin center and communication with media were some of the important tasks that unfolded in the next 30 minutes of the exercise. The entire exercise had a timeframe of approximately 5 hours, with the active part lasting for about 3 hours.

3.2 Observation

The observation was carried out by two authors, whereby one was observing the work in a CCC and the other was present at the most resource-intensive emergency site. i.e. the last incident by the city center waterfront. In the CCC notes were taken while observing the operation as well as questions asked when something was perceived as unclear. It should be noted that the first author has practical experience from emergency dispatching and therefore holds some basic knowledge in this area. The on-site observation involved observing the different emergency personnel`s operation from a spot with a good overview, taking several pictures. Some questions were posed to the involved organizers and actors after the exercise both for collecting their opinions and to clarify uncertainties on the results. Stakeholders from all agencies provided comments.

3.3 Audio-log from the inter-agency call group

EMS in Norway are using the Norwegian Public Safety Network (NPSN) as a common platform for collaborative communication. The technology is built on the TETRA- standard (TErrestrial Trunked RAdio).

This infrastructure provides secure communication in coverage, capacity and voice quality. The NPSN gives the users an opportunity to communicate in call groups across agencies and geographical areas. The first responder agencies in Norway use the NPSN as a key tool in their daily operations. In this paper, the audio-log studied is an inter-agency call group reserved only for first responders, named BAPS (fire-police-acute medicine cooperation). Common regulations for using the NPSN [48] provides a set of guidelines for user identification signals, when different functionalities should be used, definitions related to the NPSN and plain-radio language checks for group communication. The guidelines for use of the NPSN [49] underpin the importance of regular user exercises to secure proper practice and utilization of the functionalities.

The audio-log consists of communication between operative units and dispatchers from the police, fire and health (ambulance) services. The communication mainly originates from the following six actors; (1) Emergency dispatcher from Police CCC, (2) Emergency dispatcher from Fire CCC, (3) Emergency dispatcher from Health CCC (4) Incident Commander Coordination Point, Police officer, (5) Incident Commander Health/ ambulance personnel, (6) Incident Commander Fire and rescue services. Additionally, operative units from all mentioned services occasionally communicated in the inter-agency call group. There are other options for communication in the NPSN, for instance, the stakeholders can communicate in agency-internal call groups or in one-to-one conversations during the operation. The studied inter-agency call-group functions as a collaboration channel for the first responders, and it is required for all actors in these agencies to continually listen to this group.

The audio-log had several tracks, i.e. the recording of the communication was divided into several audio files in the record system and consisted of a total of 4,25 hours. The tracks show the actual timeline with both silence and messages, and all tracks were transcribed to ensure the completeness of all messages. All sequences of the events were further reconstructed into a complete dataset and systematized with the following information; 1) the origin of the information; 2) the recipient of the information, and 3) the information content. The dataset was also triangulated with the real-time logs documented by the police during the drill. The authors discussed and classified the messages into several categories (Table 2). The categorization used an inductive method and was developed gradually through classification and reclassification based on the content of the messages until a stable, unique category framework emerged. The process narrowed down the original 22 categories into 14 categories, as listed in Table 2. The categories aim to be sufficiently specific to reflect the content of the messages, but still also generic enough to to be used in other similar cases [50]. Some of the categories relate to the important features of a COP (Table 1), e.g., COP feature number 1, 2 and 3 in Table 1 are mirrored in the "Situation Report" and "Location" categories (Table 2) as the actors shared their SA and provided the collaborative agencies with important information from the operation and environment. The categories "Action", "action plan" and "request" are related to feature number 5. Feature 4 and 6 are related to "report barriers", as different terminology and information overload can represent hindrances in the task execution. In brief, analyzing the features of a COP can be used for systematic learning after exercises, especially as provided by audio-log post-hoc analysis of real-time communication.

Table 2: Communication Exchange Categories

Categories	Coverage
Situation Reports	Information flow that involves new and updated information regarding the emergency.
Confirmation	Statements that express the agencies' acknowledgment (heard, known, understood) information or actions.
Action Plan	Statements which imply the agencies 'plan for action in order to respond to the current state.
Request	Request for updated information, resources or support
Action	Actions taken and reported in BAPS
Location	Providing or confirming a current location or being in a wrong location
Contacting	The actor tries to contact one or several actors
No Answer	When the addressed actor(s) did not reply to the contact request
Offer resources	When one agency offers resources relative to the situation
New Emergency event	Notifications on new emergency events relative to the operation
Common Understanding	Information on the situation and all involved agencies confirm that they have received and understood.
Report barriers	Reports of barriers when performing tasks, such as missing equipment or conflicts with other involved parties.
Error	Disruptions in the call group (such as human mistakes).
Information Mismatch	When actors have different SA in a specific situation.

4. Results

In this section, we present the results of our communication analysis. No actual contents of the

communication in the audio-logs are presented, to protect the stakeholder's privacy.

However, both the timeline and actual conversations have been documented, allowing us to trace back the actual messages. Some of the stakeholder's comments are cited as validation for the results. It is necessary to consider several issues regarding these comments. For instance, each comment mirror one person's opinion and is likely influenced by post-hoc rationalization [51].

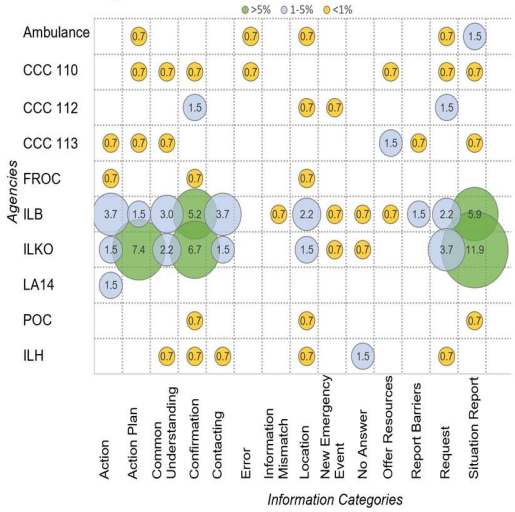

Figure 2 Information being exchanged by each agency (%)

Figure 2 presents an overview of the percentage of categories exchanged by the agencies, whereas the total number of messages is 134. As can be seen, the figure depicts that ILKO and ILB (see table 3 explaining abbreviations) were the most active agencies, especially on communicating "action plan", which was frequently followed by "confirmation" in a number of messages.

Table 3: List of Abbreviations

Abbreviation	Description
BAPS	Fire, health – and police services inter-agency call group
ILKO	Incident commander Point, Police officer
ILB	Incident Commander, Fire and rescue personnel
ILH	Incident Commander, Health, ambulance personnel.
LA14	Ambulance Helicopter
POC	Police Operative Car
FROC	Fire-and rescue Operative Car
Ambulance	Ambulance team
CCC 110	Command and Control Center, Fire and rescue
CCC 112	Command and Control Center, Police Services
CCC 113	Command and Control Center, Health services
NPSN	Norwegian Public Safety Network

These two organizations played a key role in reporting situations, especially ILKO. In this terror act case, the police have the superior responsibility of the operation. Thus, it is natural that they received most information from their CCC and took responsibility for building a COP. For ILB, this situation was resource-intensive, requiring the mobilization of a truck (to stop an uncontrolled bus) and divers (for rescuing victims in the water). The ambulance personnel carried out the treatment of the victims and would "*not spend much time on communication in BAPS*" [stakeholder comment].

To analyze the development of the inter-agency interactions when building the COP, we developed chord diagrams. The diagrams show the communication flow among the agencies, of which the chord runs from the originator agency to the recipient agency, furthermore, the more volume in the chord, the higher number of messages. Information categories being exchanged are presented as bar charts. The scenario guidelines and messages in the audio-log revealed that the crisis could be divided into three phases: the alert phase (when the three CCCs alerted the different response teams), the escalation phase (when the operative units are starting to comprehend the crisis), and response (when all involved agencies are managing the crisis).

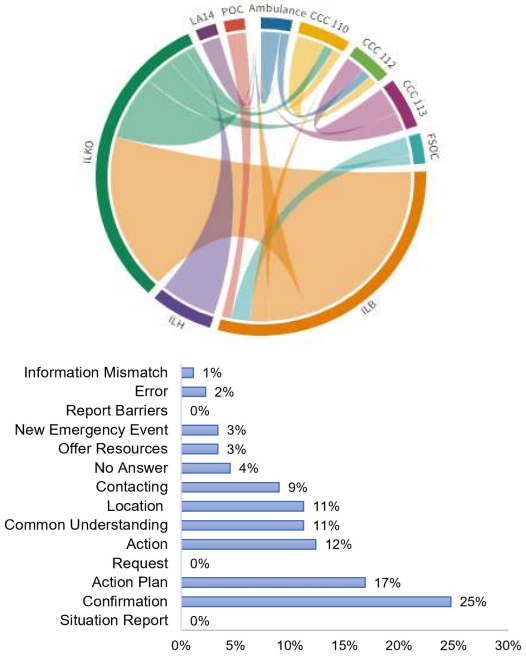

Figure 3 Multi-agency interactions (upper) and information being exchanged (bottom), 10:00-10:30

1. Alert phase (10:00-10:30)

In this phase the number of messages was at the highest with 88 messages being exchanged. ILKO and ILB communicated with each other with a considerable higher frequency than the other actors. But as the chord diagram shows, ILKO also addressed CCC 113 and CCC 110. ILKO was in charge of the operation and provided the others with critical information. ILB was also active. The fire and rescue services hold the responsibility for the operation until the police are on site. ILKO got updated information until the time they were present.

There are several categories used in the alert phase; where "confirmation" represents 25% of the messages. As the bar chart presents, the messages are concerning several features regarding the agencies' SA. The categories "action", "action plan" and "location" are all representing an increasing SA based in the category "common understanding", representing that information exchanged in the BAPS call group was confirmed and understood by all agencies. One could interpret this as if all agencies in this phase were on the alert and followed the procedure for confirming.

The high percent of the category "confirmation" related to the confirmation that they heard and understood messages in the other categories. The "situation reports" would typically be communicated in the different internal-agency call groups which provide the agency-specific CCCs important information due to their profession.

2. Escalated phase (10:30-11:00)

In this phase, the number of messages was 20. All the agencies were active in BAPS, but ILB was far more active than the rest (Figure 4). In this phase, the operative units on site prepared themselves on the most resource-intensive incident, and the fire and rescue services had many tasks concerning the victims in the water. At this time, they would need as much information as possible. The situation was chaotic, which could explain the high frequency of "requests" and "situation reports". In practice, these types of messages contain requests of updated and/or more information, resources or support. We can also observe that the category "offer resources" is present, which implies that the stakeholders comprehended the situation. Thus, they can anticipate that the situation required more resources than the current state. The lack of "confirmation" can be a result of the busy situation where the actors had a lot going on both on site and in other call groups. As one stakeholder characterized the situation; "*Simply a mental overload*" [Stakeholder].

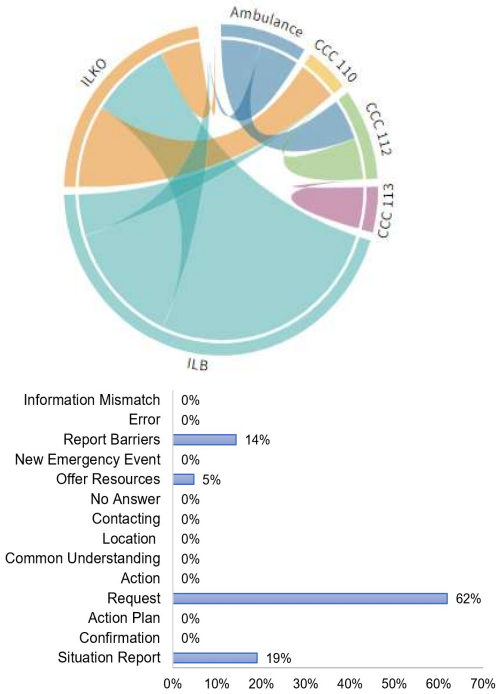

Figure 4 Multi-agency interactions (upper) and information being exchanged (bottom), 10:30-11:00

3. Response phase (11:00-13:00)

In this phase, the number of messages was 26. The actors were working with agency-specific tasks and started to get an overview of the situation. As this was an act of terror, the police had a major responsibility to make the situation safe for both the collaborative agencies and the civil people present at the emergency site. This can explain why ILKO stands for most of the communication in BAPS as can be observed in the chord diagram (Figure 5). The terrorist was not arrested yet in this phase. All communications were in the category "Situation Reports". It shows that the use of BAPS is for building a COP by providing all agencies in the call group with information that is seen as common information needs. The lack of confirmation might have several reasons; firstly ILKO, ILB and ILH were all located at the assembly place for injured and deceased and did not need to use BAPS to confirm. They only used the call group for providing other actors with information. Secondly, the agencies might use the internal agency call groups for both communication and confirmation. Third, the actors were too busy handling the mass causalities for confirming.

Ideally, the "situation reports" should be confirmed by all agencies in BAPS. The lack of this can be explained by the assumption that the messages are not as critical as in the previous phases. It might also be caused by the

professional culture and needs more attention. As one actor stated after seeing the results; "*Clearly we must repeat our messages when we don`t get confirmation" [Stakeholder].*

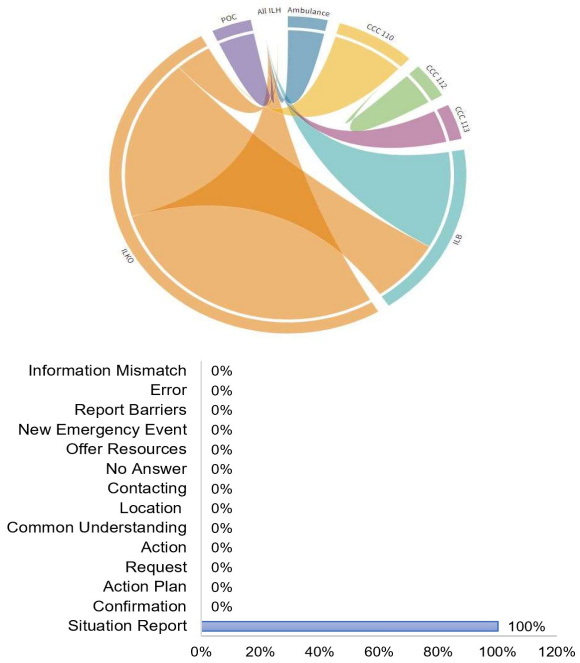

Figure 5 Multi-agency interactions (upper) and information being exchanged (bottom), 11:00-13:00

5. Discussion

The results for all phases in the operation can provide an overall picture of the collaborative communication for building a COP. In the alert phase, a diversity of categories is being exchanged and the category "common understanding" shows that most of the information is understood by all stakeholders. It seems like the building of a COP is effective in the alert phase. The maintenance of the COP in the next phases (escalated and response phase) is less obvious. In the escalated phase, the situation was chaotic, and the stakeholders struggled to maintain a COP by using the category "request" most frequently. In the response phase, the stakeholders gained more control and provided each other with information. If this means that they maintained a COP is hard to conclude on, because of the absence of the "confirmation" category. This should ideally have been validated through retrospective interviews with stakeholder. Nevertheless, based on the observations, stakeholders' comments and the messages` content, there is reason to believe that a COP was established in the two last phases. If the COP was absent, we assume the categories "request", "contacting" and "information mismatch" would have been used to some extent.

It is important to consider the fact that this is based on an exercise, which despite being planned to be as realistic as possible does not necessarily echo a real event. Exercises are fictitious and constructed and cannot provide the same effects as a real event, because of the participants' awareness that it is not real [25]. Furthermore, this case was an act of terror with multiple incidents, which represents an extraordinary situation. Because of this, the communication in BAPS does not mirror an ordinary multi-agency emergency operation. Nevertheless, this case was used for developing the categories and a methodology to analyze COP which we argue can be reusable in other full-scale exercises and evaluation after real events. Several of the features of the COP (table 1) can be identified in the analysis. Firstly, different levels of SA within the agencies can be observed through the categories "common understanding", "action" and "action plan". These categories indicate the actors` perception of elements in the environment and that they comprehend the current status.

The fact that these categories are frequently used in the alert phase can demonstrate that the agencies` communication embraces several important features of a COP. For instance, the actors create SA (feature 1) and by sharing information (feature 3 and 5) they depict knowledge on each other's operational modus (feature 2) in the alert phase of this exercise. In the escalated phase the situation appeared as chaotic, and the high frequency of the "request" category can show that the agencies know the others` capabilities (feature 2) and requests for information or some sort of action. The last phase clearly reveals communication of information that is assumed to be important for the collaborative agencies (feature 3 and 5) by offering each other "situation reports". Regarding the harmonized terminology and standardized framework (feature 4 and 6) post hoc analysis of audio-logs provide a good opportunity to investigate this, but in that case, it would be necessary to compare the communication to the standards being used. In this case study, these standards do not exist in any textual documents. To analyze this, interviews with key stakeholders had to be required.

The first responder agencies have pre-defined tasks and goals which means that the messages` content and purpose are relevant for several different operations and can therefore be reusable for different settings. The audio-logs from emergency operations provides access to the actual real-time communication during the operation including the timeline. This gives the opportunity to capture the detailed information being exchanged in different stages of the operation. The fact that the actors use other ways to communicate internally

in their associated agency and one-to-one conversations in the NPSN poses a challenge related to getting the whole picture. Even if the BAPS call group exists for collaborative communication, some of this information is then taking place outside this call group. Other imaginable limitations are the possibility of missing tracks in audio-logs, legal challenges related to getting access to audio-logs from real events and the nearly unavoidable requirement of the basic knowledge of this sort of emergency management operations. However, if the goal is to identify important features in one particular area, audio-logs provide real-time communication and the actual timeline in the operation.

6. Conclusions and Future Work

By using the important features for a COP, it is possible to evaluate the achievement and maintenance of COP during an emergency operation. The features are (1) Creation and maintenance of different levels of SA within the involved agencies (2) Knowledge of each other`s operational modus (3) Effective and time-specific communication on important static and dynamic environmental features, shared elements and common critical cues (4) harmonized terminology (5) Sharing useful comprehension of the current situation and actions/action planning important for the collaboration, and (6) Follow a standardized framework for the communication. The categories developed in this case study aim to be reusable for post hoc analysis of the real-time communication related to establishing a COP in similar cases. We argue that this methodology can be an important supplement to textual reports and retrospective interviews for future evaluations of both full-scale exercises and real events.

The study`s findings may inspire stakeholders and other researchers to further investigate the important features of a COP in exercises and real events, and use audio-logs and categories of messages to elicit a dynamic development of a COP. Currently, this methodology will be validated further in different scenarios. This can be achieved by applying the audio-log analysis in other exercises as supplementation for other evaluation methods.

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SMS-based Real-time Data Collection for Evaluation of Situational Awareness and Common Operational Picture: Lessons Learned from A Field Exercise

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ABSTRACT

Managing complex multi-agency emergency operations requires that the key actors have a holistic, correct and dynamic situational awareness (SA) and that the involved actors establish a common operational picture (COP). Establishing SA and COP are key objectives in many multi-agency exercises, however, reported research shows limitations in existing methods and approaches for collecting the data required for evaluating this. By being able to capture near real-time information during different phases of the exercise we will be better positioned to identify what works well and what does not work in the process of establishing SA and COP. Our paper presents an example of real-time data collection using SMS during a multi-agency field exercise. Overall, the results support the idea of this as an effective method for collecting real-time data for analyzing the formation of SA and a COP among actors in emergency management.

Keywords
Real-time Data Collection, Emergency Exercises, Situational Awareness, Common Operational Picture.

INTRODUCTION

Because of the risk for jeopardizing the safety and quality of an emergency operation, it is difficult for researchers to observe the situational awareness of involved actors during a crisis. Thus, exercises provide the best option for studying related behavior (Wolbers, Boersma and Groenewegen, 2018). The involved agencies must enhance their capabilities to handle mass casualty incidents by practicing and evaluating new and established knowledge in full-scale regional exercises (Klima et al., 2012). Literature related to emergency management organizations request more studies focusing on the outcome of collaboration in exercises (Berlin and Carlström, 2015).

Providing training in testing collaboration, communication, standard procedures, building common operational picture (COP) and common situational understanding to enhance collaborative skills and situational awareness are training targets in many multi-agency exercises. However, reported research shows limitations in existing methods for collecting data related to emergency incidents (Altevogt, Wizemann and Reeve, 2015) and exercises

(Ingrassia et al., 2012). In addition, it is a challenge to evaluate full scale-drills involving several emergency management services because the actors have different views and perceptions based on their domain-specific expertise (Imoussaten, Montmain and Mauris, 2014) and their narrative is likely to be influenced by post-hoc rationalization (Bygstad and Munkvold, 2011). This represents a problem, since evaluations are mostly based on observation, textual sources such as reports and post-hoc interviews, and less on real-time data reflecting the actors' SA during the exercise. The practices in emergency management are highly contextualized and the involved actors "*often cannot articulate how they do what they do unless they are in the process of doing it*" (Barley and Kunda, 2001, p. 85).

When handling emergencies, first responders and their collaborating organizations make decisions and perform actions based on the recognition of an event, the interpretation of their observations and predictions of the outcome in different settings (Berlin and Carlström, 2008), which are all core elements of SA (Hunter, Porter and Williams, 2019). Further, an actor`s level of SA provides a crucial foundation for decision making (Endsley, 1995). The individuals` explanation of the situation is exchanged with collaborative actors and then negotiated into a shared social information (Stieglitz, Mirbabaie and Milde, 2018) derived from the common goals. The actors` SA at different stages in the operation has a huge impact on the process for building a COP (Steen-Tveit, Radianti and Munkvold, 2020), which is shown to be an important component in making an emergency operation efficient (Karagiannis and Synolakis, 2016).

This paper presents a field experiment of using a SMS-based survey method for near real-time data collection among important decision-makers during a full-scale regional exercise with a forest fire scenario. The SMS consisted of a link to a small survey with eight questions and was delivered to fifteen key actors in two different stages of the exercise. The questions concerned the actors` SA and whether they had access to sufficient information for establishing SA. Based on analysis of the SMS responses and interviews with participating actors about the method after the exercise, the paper presents lessons learned and recommendations for future real-time data collection using SMS. As will be illustrated, this method provides a possibility to measure the differences in the actors' SA on important elements of the emergency situation at given stages in the operation, and further compare this information to evaluate to what degree a COP is established.

The next section briefly presents a summary of SA and COP as a foundation for successful emergency management, and some currently used evaluation practices. Then the method for collecting the real-time data is described, followed by results from the survey during the field exercise. Finally, the findings are discussed and implications for further use of the SMS data collection method for evaluating SA and COP in multi-agency emergency operations are presented.

RELATED RESEARCH

Organizations that handle emergencies must make important decisions with potential crucial outcomes based on minimal information and under high time pressure (Magnussen et al., 2018). Live full-scale exercises provide an important environment for learning about the collaboration processes in situ and contribute with a possibility for eliciting the actors` cognitive and emotional response similar to the responses in real events (Waring, 2019). The involved actors` intention is to achieve a collective perception, however in evaluations they are most likely to transfer their own perception of the situations based on their own professional standpoint (Imoussaten et al., 2014). The evaluation of multi-agency exercises seems to be mainly relying on textual sources such as reports, observations and interviews. Therefore, objective evaluation is an issue (Gryth et al., 2010) because of the different situational understanding and knowledge among the various decision-makers (Ju and Wang, 2012). Post-hoc interviews rely on the actors` memories of the situation and one must consider that people forget and that memories are an ongoing process. For instance, it is difficult to separate memories and beliefs because they rely on each other (Shaw, 2018) whereas *"Memories are beliefs about what happened, and beliefs are constructed from, and reinforced by, memories"* (Raye, 2000, p. 36). Real-time data collection can provide valuable insights in situ and avoid some of the memory biases that might occur.

Over the past 40 years, SA as a factor in human decision-making processes has been a focus for a considerable amount of research in different domains. Endsley's (1995) SA theory is one of the most influential models in this research, based on the following definition: "*Situation Awareness is the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and projection of their status in the near future*" (Endsley, 1995, p. 36). Research from the aviation industry has shown that lack of SA as a human factor might lead to poor outcomes and errors in the management of operations (Endsley and Garland, 2000), and notably 88 % of the major accidents in aviation has been related to poor SA (e.g. Cak, Say and Misirlisoy, 2019; Endsley, 1995). Endsley's model divides SA into three levels that can be analyzed: (1) perceiving the elements in the environment, (2) comprehending the current situation, and (3) projecting the future status of the situation (e.g. Endsley, 1995; Endsley and Garland, 2000). Based on this concept it is possible to investigate how individuals

develop SA and what it comprises (Stanton, Salmon, Walker, Salas and Hancock, 2017). Another interpretation of SA is "*the combining of new information with existing knowledge in working memory and the development of a composite picture of the situation along with projections of future status and subsequent decisions as to appropriate courses of action to take*" (Fracker, 1991; cited in Salmon et al., 2007, p. 408) This definition emphasizes how the actors combine existing knowledge and experience into the individual development of SA, coupled to the dynamics in the situation they are in at different stages in time. Time itself is thus an important factor to consider regarding each actor`s SA because SA is connected to how the situation evolves (Fracker, 1991).

One can measure the performance of an exercise, but the measurement of SA can provide a greater sensitivity of the evaluation when considering SA as a state of knowledge in a dynamic situation (Endsley and Garland, 2000). However, the process of achieving SA also involves several cognitive processes that are more complex to measure than to evaluate the state of knowledge at different stages in an event (e.g. Edgar et al., 2018; Luokkala and Virrantaus, 2014; Salmon et al., 2008). There are several methods for evaluating different Command and Control Center (CCC) operators` SA such as SAGAT, SPAM, response time, errors (Endsley, 2019). SAGAT is a method where they perform different simulations of tasks or scenarios. At selected times, the performances are frozen and the actors` answers questions either verbally, in writing or on a computer. This is a real time data collection method that is found to be highly sensitive, and criticism of this says that the freezing of the scenarios is intrusive. SPAM is a real time data collection method that avoids the freezing, where the actor is asked verbally while he or she perform the operational tasks. Nevertheless, criticism have also been raised about the intrusiveness of SPAM (Endsley, 2019).

The different actors` SA is a crucial factor for the success of the operation, however, the COP is another important component related to multi-agency operations. Norway experienced a terror attack in 2011 where the commission report concluded that we need to improve the focus on SA and COP. As a direct consequence, a new collaboration principle was added to the Norwegian emergency preparedness regulations (Norwegian Government, 2017). Therefore, an important focus in the crisis management domain is the SA and how the actors build a COP. The actors` SA is an important foundation for building a COP, and SA can be considered as an emergent property of the interaction between an individual and the surroundings (Edgar et al., 2018).

Since the emergency management services have become more specialized (Axelsson and Axelsson, 2006), the different organizations must collaborate for achieving the best possible outcome in large crisis operations (e.g. Kapucu, 2008). To be efficient in the collaboration process it is important to share critical information for building and maintaining a COP. This is accomplished by a process of connecting the agency-specific actions into a common arrangement (Wolbers et al., 2018) and further collect operational specific static and dynamic information from different sources in the environment and share the common information needed with the relevant organizations (Blandford and Wong, 2004). However, even though collaboration exercises are supposed to improve cross-sectional interactions (Kim, 2013), collaboration is proved to be hard to practice even in collaboration exercises, and the outcome has limited usefulness in real operations (Berlin and Carlström, 2008; Berlin and Carlström, 2015). Why this seems to be the case is an ongoing discussion, and literature shows different examples such as inadequate focus on learning aspects and too much dependence on standards (Sørensen et al., 2019). Other findings indicate that the focus is mostly on internal routines and skills, and less on collaboration capacities (Andersson, Carlstrom, Ahgren and Berlin, 2014). Another reason could be the lack of dynamic information on the different involved actors` state of knowledge in various stages of the emergency operation, as this might provide a deeper understanding of the operational features that elicit decision-making of several actors simultaneously. The ability to discover specific important features that strengthen or prevent success in crisis management operations is an essential step towards an effective evaluation (Ingrassia et al., 2012).

SCENARIO AND METHODOLOGY

Scenario

We tested our proposed method for evaluating SA during a full-scale emergency exercise held in Norway. Every year, the County Governor's offices in Norway run this type of exercises in their respective region. The one-day exercise took place in September 2019 in two inland municipalities in southern Norway. The exercise scenario was an industrial fire that spread to the nearby forest, creating needs for evacuation of inhabitants in the affected area. The scenario also included search for a missing person. The purpose of the exercise was to train the first responder agencies and the municipal crisis management team on how to handle a serious incident and thereby strengthen crisis management skills (cooperation, coordination) and planning for such a complex scenario.

Methodology

We planned the field trial of the evaluation method via SMS with the exercise organizer, to prepare for conducting

the data collection and investigate several elements of the key organizations` management of the crisis. Table 1 shows an overview of the respondents in our data collection.

Table 1: Respondents

Organization	Role	Data collection
Fire services	Site commander	SMS + Interview
Fire services CCC	Emergency dispatcher	SMS + Interview
Ambulance	Site commander	SMS + Interview
Ambulance CCC	Emergency dispatcher	SMS
Ambulance CCC	Site commander	SMS
Police services	Operative unit	SMS
Police services	Site commander	SMS + Interview
Police services CCC	Emergency dispatcher	SMS + Interview
Municipality	Emergency coordinator	SMS + Interview
Municipality	Emergency coordinator	SMS + Interview
Municipality	Municipal Chief Executive	SMS + Interview
Media college	Journalist student	SMS
Media college	Journalist teacher	SMS
Red Cross	Site commander	SMS
Red Cross	Operative Unit	SMS
County Governor`s office	Counsellor	SMS + Interview

The respondents included key actors, ranging from the first responder services (police, fire and health services), two involved municipalities, the county governor's office and the voluntary organization Red Cross. All these actors had some degree of authority to make decisions. In addition, the SMS also was sent to one teacher and one student at a local media college acting as reporters to cover the emergency situation. Three actors who received the SMS did not answer. It could be several reasons for the missing response. They may have overlooked the SMS or may have been prohibited from responding due to the high time pressure in their operation. As these actors did not respond to any of the two SMS messages, the answers to the first and second SMS are from the same respondents.

SMS survey

The questions in the SMS survey (Table 2) were based on some of the important elements in achieving SA such as receiving information (questions 1,2 and 3), how to comprehend the information (question 4), prediction of future status (question 5) and knowledge about available resources (questions 6 and 7). The seven questions were administered using SurveyXact (SurveyXact.no). Some of the questions were designed as multiple choice (shown in Table 3), and also with possibility to include a free text response to elaborate. An example would be question 2 "Who gave you the latest situation report?" where the option; "other" (see question 2 in Table 2) had an open line to elaborate the answer, thus who gave the latest situation report.

Table 2: Questions in the SMS

Number	Question
1	Have you been provided with sufficient information to form an understanding of the situation?
2	Who gave you the latest situation report?
3	How did you receive the information?
4	How do you understand the scope of the fire?
5	Which of the following critical community features do you believe is threatened?
6	Are all necessary resources for managing the situation present?
7	Do you know the location of the other resources?

Two actors from the Ambulance services and the Ambulance Command and Control Center (C3) functioned as pilots and received the SMS some time before the exercise to provide us with possible improvements and clarifications. This led to some updates to the original questions. The participants in the exercise were contacted a few days in advance and asked if they were willing to receive the SMS survey on their private cell phone. A day in advance, researchers provided a reminder to all confirmed participants, also via SMS, on this SMS survey under the exercise. The SMS was sent from the researchers` lab at two occasions selected based on the scenario

description, see timeline in Figure 1.

Figure 1: Exercise timeline

The content of the SMS provided the privacy statements for handling the data, brief information of the project, and the timeline for answering the questions, i.e. within fifteen minutes after receiving the message. The SMS contained a link to the survey.

Interviews

Nine interviews were conducted during the week after the exercise. The semi-structured interviews mainly covered questions about the participants' different working methodologies and tools, but they were also asked about their experience with receiving the SMS during the exercise. The interviews were performed by four different researchers, lasting from 45 to 60 minutes. The interviews were all recorded and transcribed in full.

FINDINGS AND DISCUSSION

Table 3 summarizes the responses of the two rounds of the SMS survey.

Table 3 Responses from the two rounds of SMS data collection

Questions	First SMS		Second SMS	
	Answer	%	Answer	%
1. Have you been provided with sufficient information to form an understanding of the situation?	Yes (8/13)	57%	Yes (6/9)	67%
	No (5/13)	43%	No (3/9)	33%
2. Who gave you the latest situation report?	Own CCC (3/13)	23%	Own CCC (3/9)	33%
	Other CCC (1/13)	8%	Other CCC	0
	Operative Unit (5/13)	38%	Operative Unit (1/9)	11%
	Other (4/13)	31%	Other (5/9)	56%
3. How did you receive the information?	Specific call group (2/13)	15%	Specific call group (2/9)	22%
	BAPS*	0%	BAPS*	0%
	Other common call group	0%	Other common call group	0%
	Phone call (5/13)	39%	Phone call (1/9)	11%
	Verbally from colleagues (6/13)	46%	Verbally from colleagues (6/9)	67%
4. How do you understand the scope of the fire?	Small-controlled (1/13)	8%	Small-controlled	0%
	Medium-controlled but can evolve to uncontrolled (4/13)	31%	Medium-controlled but can evolve to uncontrolled (3/9)	34%
	Big-uncontrolled (3/13)	23%	Big-uncontrolled (4/9)	44%
	I don't know (5/13)	38%	I don't know (2/9)	22%
5. Which of the following critical community features do you believe is threatened?**	Housing (6/13)	50%	Housing (4/9)	44%
	Electronic communication (1/13)	8%	Electronic communication (1/9)	11%
	Accessibility (5/13)	42%	Accessibility (4/9)	44%
	Energy supply (1/13)	8%	Energy supply (1/9)	11%
	Vulnerable group (4/13)	33%	Vulnerable group (6/9)	67%
	Operative personnel (5/13)	42%	Operative personnel (3/9)	33%
6. Are all necessary resources for managing the situation present?	Yes (5/13)	36%	Yes (2/9)	22%
	No, we lack some (5/13)	36%	No, we lack some (5/9)	56%
	I don't know (3/13)	28%	I don't know (2/9)	22%
7. Do you know the location of the other resources?	Yes (9/13)	56%	Yes (6/9)	67%
	No (4/13)	44%	No (3/9)	33%

* Collaborative call group for fire, health and police.

** Respondents could select more than one answer.

First SMS: The SMS survey provided answers from several key actors in the exercise (ref. Table 1). Questions 1, 2 and 3 concerned receiving information for building SA. The first question asked if the participant perceived to have sufficient information to form an understanding of the situation. The first SMS survey was distributed one hour after start of the exercise, and the situation had just been escalated by a fire in a factory with people inside (see timeline in Figure 1). The answers indicate that the majority (57 %) perceived to have sufficient information at this stage. However, it is somewhat surprising that as many as 43 % of the key actors experienced that they did not have enough information to form SA. Using the Norwegian Public Safety Network (NPSN), which is a common collaborative platform for both internal and inter-agency verbal communication, it should be possible to provide complementary information to all key actors simultaneously, and thus provide the involved stakeholders with shared information needed for building a COP. However, not all municipalities have yet taken the NPSN in use.

The observed differences in the perception of having been provided with sufficient information or not may have several reasons. Firstly, from the answers of Question 3 (Table 3) the information seems to be spread verbally from colleagues on site or in the communication hubs (46 %), and not via the NPSN. This shows that the information mainly did not come directly from the CCCs but seemed to be communicated on site. Secondly, since the Norwegian emergency management services do not have other shared information systems such as a common map interface, the reported lack of situational understanding may indicate that verbal descriptions only are not sufficient to form a SA in this kind of complex scenario. Thirdly, it may indicate that the provided or available information flow did not fulfill the different actors` internal information needs. The answers to Question 2 might indicate the natural communication paths because of the many different emergency management services involved using different tools and procedures for communication. However, since no communication was provided in the collaborative call group (BAPS) (Question 3) or by other CCC (8%) (Question 2), there seems to be limited common information provided in the NPSN. Overall, the response to Questions 1, 2 and 3 show a lack of any fixed structure in the information sharing process for building a COP. The answers to question 4 showing divided understanding of the scope of the fire, indicate that the communication flow did not satisfy the information needs. This assumption is reinforced by the answers to Question 5, showing relatively little consensus on the threats from the fire to different critical community features, and thus indicating a lack of established COP in this area. The varying responses to Questions 6 and 7 also accord with the observation from Questions 1 and 4, that the SA was limited at this stage of the crisis.

Second SMS: The second round of the SMS survey was sent three hours into the exercise, when the situation had escalated, and the fire had spread to the surrounding forest area (Figure 1). While the fire was still developing also in this stage, the answers to Question 1 related to receiving information indicate that the majority of the actors had been provided with sufficient information to a greater extent than earlier in the operation, thus reflecting a higher degree of SA. Regarding building a COP, the information was still mainly shared verbally outside the NPSN, except for 22 % shared in a specific call group. The answers still show some differences in the perception of the scope of the fire (Question 4) and the threatened community features (Question 5). Answers to question 6 and 7 show that over 50 % experienced that this crisis required more resources than what were available at this stage of the operation, and that 67 % knew where the involved resources were at that time. Based on this, we assume a COP had been established in this particular area.

The responses from the second SMS indicate that the actors had a better understanding of the situation and to a greater extent experienced to have sufficient information about the fire in order to have an adequate situational understanding. However, the answers also indicate several differences in the perceptions which may be caused by several reasons, for instance, even if the operation had lasted for three hours, there were many organizations involved at various locations, using different technological tools, and with different tasks and goals. Naturally, the organizations in their handling of the situation will focus mainly on their own information needs. Time may not allow for obtaining knowledge on the tasks of other actors, and the key information must be in focus. With 56 % responding that the available resources were insufficient, one can assume that the operation was partly hectic.

Interviews results

Out of the nine actors we interviewed, six had answered one or both SMS surveys. From the interview we learned that one of the actors who was not responding got interrupted when she tried to answer the survey. The other two were functioning as operative personnel. One of them explained the lack of participation by forgetting it, he did not heed his cellphone throughout the exercise. The other participant experienced too much time pressure and the tasks she was responsible for could not be interrupted. The key goal for the operative units in the exercise was training on collaboration and coordination at the emergency site and checking their cellphone could be difficult in this situation. However, several other operative units did answer, this can be explained by the varying number

of tasks both in general and at the specific time when they received the SMS. Several actors mentioned the time pressure in the interviews and emphasized that such exercises tend to be very hectic. Some also pointed out that they were a bit stressed out when answering the survey. This is also the reason why three actors only had time to answer the first round. Two actors suggested that the exercise management ought to remind the participants to answer the survey, one of them stating that *"in collaboration with the exercise management, I would like someone to tell me: "now (name) take five minutes timeout", and then I would be more prepared to answer".* Another participant from a CCC suggested to be reminded via their own information system such as internal mail, as then the reminder would be visible in their working area. The cell phone is typically not in focus in these situations.

The participants on the whole demonstrated clear opinions about the method and were mainly positive and expressed understanding for the purpose. They also appreciated the goal for the SMS, because evaluation of SA and COP is difficult and important areas for practice. An interviewee pointed out that it was absolutely necessary that they were prepared for it and knew why they should answer, and what the results could provide. Without this, it could be perceived as a disruptive element. This view was echoed by another informant who argued that it was crucial that the idea of sending the SMS was introduced early in the planning process, and by this preparing the actors. It can be difficult to implement new elements in such hectic environments and established processes as this type of exercise, and it might be even more difficult when it is researchers and non-practitioners who introduce it.

When asked about the content of the survey, some informants argued that it should be possible to answer with more nuance, for example as one interviewee said; *"It was a bit simple, I had many things I would like to explain"* and another commented that; *"I would like to have more possibility to differentiate the answers, the outcome might be too simple like this (...)"*. Yet, none of the participants provided any textual elaboration to the questions opening for this (see Table 3). This suggests that the survey should consist exclusively of multiple-choice questions and not rely on open answers. Overall, the comment "*I think it was good that it was relatively short, or else it would be too complex to answer"* illustrates that this kind of data collection in such environment must be simple and quick to answer. Still, it could be considered to provide more response alternatives for some questions, for greater detail and nuance. One option could be to arrange the possibility for the respondents to verbally answer by a voice message.

CONCLUSION

The aim of this research was to examine how we can use SMS to be able to capture near real-time information during different phases of an exercise, and to analyze whether this can make us be better positioned to identify what works well and what does not work in the process of establishing SA and COP. The results from the two rounds of the SMS survey provided some indicators of the participants` SA in the two stages. Further, it is possible to discuss the COP when investigating the differences and similarities in the answers.

The results of the qualitative interviews support the idea of this being an effective and fruitful method for collecting real-time data, however, it is important to consider the high time pressure and complex tasks in emergency exercises. While this method seems promising for analyzing SA, it should be implemented cautiously to maintain balance between the use of too simple and too complex questions and response options. In addition, open questions should be avoided. Further, it is important to incorporate this type of data collection early in the exercise planning, to be able to prepare the participants and ensure their contribution.

However, this method also has some limitations that should be considered in future studies. Emergency operations, even exercises, create a stressful environment which can hinder the informants from answering, or influence the accuracy of the answers. In addition, exercises are always different from real events in various ways (Berlin and Carlström, 2014) and the logic in the working processes might be different from real events and further influence the answers. While the differences in collecting data from a link instead of personally asking the informants (such as in SPAM and SAGAT) provide some issues such as the possibility to ask follow- up questions and clarify answers, there are also some benefits. For instance, the disturbance is less than having a researcher coming into the emergency site during the operation, which again may impair the realism and tamper with the actors' structures (Ingrassia et al., 2012). Further, there is no influence from the researcher, and it provides the opportunity to simultaneously include a large number of respondents.

Despite these limitations, the study offers relevant implications for near real-time data collection. A natural progression of this work is to develop the questions to be as easy as possible for the participants to answer in such hectic situations. Further experimentation using a broader range of the possibilities of smartphone technology, such as GPS for investigating the connection between level of SA and the location of the actor, is recommended. Lessons learned from our experiment shows that open questions will not be answered, but that it perhaps should be more response alternatives provided. Former studies report challenges for novice first responders in handling the workload due to limitations in their attention and working memory capacities (Cak et al., 2019), and the real-

time data collection suggested by our method might reveal differences in the SA between novices and experts. Through this one can identify what elements that must be strengthened in the training processes of novices. This potential should be addressed in further research.

This study represents a first attempt to examine the use of SMS-based data collection for analyzing the formation of SA and a COP among actors in emergency management. We plan to further test this method in different exercise scenarios, to refine the method and its use.

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Identifying information requirements for improving the common operational picture in multi-agency operations

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ABSTRACT

While there exists a considerable body of literature on the importance of a common operational picture (COP) in multi-agency emergency operations, the COP concept itself still lacks a univocal definition. Despite the lack of consensus regarding the mechanisms underlying the COP, the literature implies a level of consistency in the focus on sharing critical information. Based on interviews with Norwegian emergency management stakeholders, this study investigates common information requirements for emergency management services and presents an example of a framework for structuring the sharing of critical information and building a COP. Termed 'the window report', this framework is used among emergency stakeholders in Norway and Sweden. The study identified eight common information requirement categories for managing extreme weather scenarios. With a focus on common information needs and a process for structured information sharing, future strategic emergency management planning might take a more holistic perspective on cross-sectoral operations than in current practice.

Keywords

Situational awareness, common operational picture, information sharing, common information requirements, multi-agency emergency operations

INTRODUCTION

There is a gap between theory and practice in multi-agency crisis management, which involves, among other things, the important domain of information sharing (Janssen, Lee, Bharosa and Cresswell, 2010). Furthermore, crisis operations are affected by ineffective information sharing processes due to the lack of knowledge regarding specific information needs in collaborative organizations (Munkvold et al., 2019).

Climate change results in an increase in extreme weather events (Stott, 2016). The emergency management related to these events is different from that of other events that are more limited in scope because extreme weather has consequences with cascading effects, threatening human survival and causing damage to property and critical infrastructure. These events often hit critical functions in society, such as buildings, electricity, telecommunications, and the Internet. They require extraordinary efforts from authorities and cannot be handled through ordinary routines and structures. Operational responses to natural disasters require coordination with organizations beyond regular emergency management services that handle crises on a daily basis. In addition, the first hours of a disaster are complex and chaotic, and emergency management in this critical timeline is crucial for outcome success. These operations require effective collaboration and information sharing in order to reach common goals, such as saving lives and mitigating destruction. Because of several heterogenous information needs among the organizations involved, there is an inability to determine what information needs to be shared (Bharosa, Lee and Janssen, 2010), which presents bottlenecks in collaborative efforts. The literature on multi-agency crisis management emphasizes the importance of the common operational picture (COP) for the purpose of collaborating and sharing information (e.g. Bunker, Levine and Woody, 2015). Scholarly articles present the COP differently, for instance, it is sometimes presented as an information system that enables information to be presented in visual form (Luokkala, Nikander, Korpi, Virrantaus and Torkki, 2017). Other times, it is presented as a checklist of the characteristics in a certain situation within a geographical area (Wolbers and Boersma, 2013). Whether the COP is a process, a product, or an operating environment remains undefined.

There are different ways in which the organizations involved can share information in order to build a COP, one option is to communicate via technology, such as a geographic information system (GIS). The GIS uses custom symbols to display relevant operational information, such as location, topography, infrastructure, and different resources (Karagiannis and Synolakis, 2016). However, many emergency management services do not have access to a common GIS interface because they use support technologies with no interoperability across organizations. This means that they must share geographical information verbally. Several studies have addressed the difficulty of information sharing among the various actors, whereby the collection of relevant and verified information from different sources in the environment must be shared with the collaborating services (e.g. Luokkala et al., 2017; Seppänen, Mäkelä, Luokkala and Virrantaus, 2013; Steigenberger, 2016). More research is required in order to define the relevant information needs of different contexts so as to create a good situational awareness (SA) and build a COP (Seppänen and Virrantaus, 2015).

This paper aims to define common information requirement categories for multi-agency crisis management in an attempt to support the establishment of a COP during extreme weather events. Moreover, it discusses an example for how to share this information using a common practice among Norwegian first responders. The research question guiding this study is: *What common critical information is required by the multiple agencies involved to build a COP and respond to the impacts of extreme weather, such as flooding, storms, and forest fires?* The study is based on the Norwegian context and focuses on managing extreme weather scenarios in the acute phase. The target organizations are first responder agencies (fire and rescue, police, and medical services) and municipalities. The focus is on the common information requirements, not the agency-specific needs or the different information systems used in these organizations. The next section briefly presents a summary of the current practice as well as the relevant literature on SA and the COP. This is followed by a description of the research method, which consists of qualitative interviews and a web-based survey. Thereafter, the findings from the interviews are presented and discussed, followed by a conclusion.

THEORETICAL FRAMEWORK

Current practice

Changes in the global climate are engendering change in many local communities in Norway (Norwegian Ministry of Climate and Environment, 2013). Evaluations of extreme weather scenarios show that scattered emergency management is a key challenge (NOU, 2000). In larger and more complex events, such as extreme weather, municipalities play a central role, as they are tasked with safety at the local level and are, therefore, an important part of the emergency management system (Civil Protection Act, 2010). The municipality collaborates with internal and external emergency organizations in large events (Regulation on municipal emergency duty, 2011). For first responders, such as police, fire and rescue, and medical services, the features of the information they receive can have major consequences for the outcome of the operation (Schroeder et al., 2018). They rely on information that reflects the situation they are handling (Liang and Gao, 2010). In joint events, where organizations besides first responders are participating, the need for information sharing includes other actors besides the operational units and their associated command and control centers (C3). In smaller everyday operations, first responders have a long tradition of collaborating on the emergency site, for instance, the first responder on site provides other stakeholders with a "window report" in the Norwegian Public Safety Network, which is a common platform for collaborative communication. There is no univocal standard for this kind of window reporting, but the essence is to provide knowledge on, for example, position, resources, and scope (Solberg et al., 2018). An example of such a reporting structure is the Gothenburg Window used in the Swedish Police (Borglund, 2017) (Figure 1), which provides information about *place* (location), *direction* (short description on the situation), *resources* (summary of operative units on site), and *trend* (status quo, and for instance if the situation is escalating or calming down). Recently, the Norwegian C3 for police, fire and rescue, and medical services implemented new procedures for common questioning of callers in nine different cross-sectional scenarios (Dreyer, 2019). However, this strategic way of information sharing is limited to internal use for first-responder services and do not include other external organizations involved in crisis management. A Norwegian project called OPSAM (Operation Center for Collaboration and Preparedness) (Fredheim, 2017) has demonstrated the need for an efficient and streamlined information sharing process between first responders and the municipality. Other international studies have shown that there is a lack of shared protocols for communication between agencies (Bunker et al., 2015). An applicable information sharing process can contribute toward building a COP between the operational units, with their associated C3, the municipalities, and other relevant organizations that must also act within their areas of responsibility. Cross-sectional processes simplify communication, and this corresponds with a structured procedure for equal information sharing as a "window report" with prioritized content. Studies show that the use of scripts for

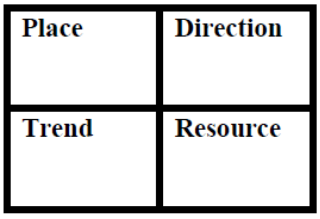

Figure 1: The Gothenburg Window (Borglund, 2017)

collaboration supports the SA of the agencies involved (Appelman & van Driel, 2005), which is important for COP building.

Situational Awareness

A substantial number of studies have pointed to SA as one of the key elements in emergency management (e.g. Dilo & Zlatanova, 2011; Endsley, 1995). It is also among the most researched topics in the domain of human factors related to emergency management (e.g. Cak, Say, and Misirlisoy, 2019). Dr. M. Endsley (1995, p. 287) made an extensive contribution to research on SA, defining it as "the perception of elements in the environment within a volume of time and space; comprehension of their meaning; and projection of their status in the near future." This definition refers to three hierarchical phases, described as levels 1, 2, and 3 SA. Level 1 SA is the first step in achieving SA and involves a perception of the relevant elements and the related attributes and dynamics connected to the specific information (Endsley, 1995). For example, a firefighter would perceive the size of the fire, topography, wind direction, and color of the smoke. Furthermore, the elements in level 1 SA provide the actor with an understanding of the situation in terms of what the different elements mean in relation to the agent's professional goals. This gives a holistic picture based on the element in level 1 SA and the professional's ability to form patterns with that information, which leads to level 2 SA (Endsley, 1995). In this case, the firefighter would understand that the wind direction, location, and topography indicate certain features about the situation. Some professional experience is required to achieve level 2 SA so as to relate the elements in level 1 SA to the relevant goals. Level 3 SA is the highest form of SA, and this involves the ability to project the future status of the situation (Endsley, 1995). For instance, the firefighter understands, based on the two previous SA levels, that the fire might spread to a populated area. The accuracy of the projection depends on the degree of the two lower levels of SA (Falkland and Wiggins, 2019). In general, the degree of SA is related to performance (e.g. Falkland and Wiggins, 2019; Jipp and Ackerman, 2016), and several studies have revealed the importance of SA in several emergency responder professions, such as firefighters (Li, Yang, Ghahramani, Becerik-Gerber, and Soibelman, 2014), military commanders (Riley, Endsley, Bolstad, and Cuevas, 2006), and pilots (Endsley and Robertson, 2000). This is further associated with fewer errors and a higher level of efficiency (Falkland and Wiggins, 2019).

Information sharing and the common operational picture

An extensive and growing body of literature has highlighted collaboration as a critical success factor in complex emergency operations (e.g. Berlin and Carlström, 2014; Bharosa et al., 2010; Kapucu, 2008), such as multi-agency management of extreme weather scenarios. Nevertheless, there is a large volume of published studies describing the problems with information sharing among emergency response organizations (e.g. Bharosa et al., 2010; Comfort, 2007; Wolbers and Boersma, 2013).

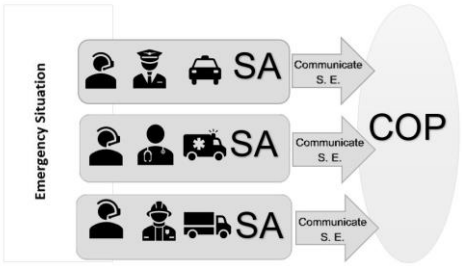

Figure 2: Agencies' SA and communication of shared elements (SE) to create a COP (Anonymous, 2020)

The COP is contemplated as a promising support in actors' development of SA and a solution to the collaboration and information sharing difficulties in the field (Comfort, 2007). However, the COP lacks a univocal definition (Wolbers and Boersma, 2013), although it consistently involves features of collaboration. A highly important element in the collaboration process is the information sharing aspect, and the accuracy of the information is essential in intensive operations (Abbas, Norris, and Parry, 2018). Actors' SA is an important basic component for the outcome of agency-specific tasks and goals, but it is also a central source in contributing to the COP. This can be briefly illustrated by first responders' communication with each other and their respective C3 (Figure 2). As Figure 2 shows, the three first-responder agencies (police, fire and rescue, and medical services) need to build SA and communicate the shared elements with each other in order to establish a COP. In multi-agency operations, including relevant organizations besides first responders, a majority of the goal-oriented operational actions are interdependent, and therefore, many of the information requirements are common and need to be shared. However, the COP is inadequate in supporting the stakeholders' SA because the COP concept generally supports management teams and does not factor in that the SA supports the different teams with their agency-specific tasks and goals (Luokkala and Virrantaus, 2014). This might result in a COP that includes all available information but does not prioritize the relevant elements that ought to be shared. In this case, the practice of an "all information to all people" approach (She et al., 2019) will result in information overload, i.e., the dissemination of redundant and irrelevant information (e.g. Ben Lazreg et al., 2018; Laakso and Palomäki, 2013). Humans have limited capacity to hold information available for processing—what is called working memory (Lauria et al., 2019). Thus, information overload complicates decision-making and creates simplified mental models (Van den Homberg et al., 2018). SA is associated with

cognitive capabilities such as attention, perception reasoning, and working memory (Cak et al., 2019). Since SA is subjective, one can say that the COP is created by the actors involved in the operation, as it consists of some SA elements, which the actor either understands must be shared based on experience or consulting with colleagues or has knowledge of through procedures, etc. Borglund (2017) acknowledged the COP as a selection of the important parts of the information available to actors—reported as descriptions and predications of the situation. Based on this, the COP is the result of both static and available dynamic information analyzed by the different actors involved, thus their SA. They must then decide what information needs to be shared and what is useless to the collaborating parts. By further drawing on the COP concept, Berggren and Johansson (2010) suggested that the COP is a GIS or map representation of the operational area and that it consists of units and fields of significance. In emergency management, this could mean visualizing the location of all the units involved, the areas of interest, evacuation spots, and the different types of resources. According to Looney (2001), several terrain features, such as road intersections, are important. This has been supported by Johansson, Hellgren, Oskarsson, and Svensson (2013), who have argued for the relevance of the ability to localize objects in the terrain of emergency management. Further, it has been suggested that the COP enables several agencies to share and view time-dependent information across a single picture (Bunker et al., 2015). Table 1 presents important features for building a COP (Steen-Tveit et al., 2020). However, several of the features require specific information that must be exchanged among the stakeholders building the COP. If these common information requirements are either missing or hidden in an overload of information, it becomes impossible to achieve the COP. Other features concern common preparation and training. Feature 6 is a direct call to use a framework or structure, such as the Gothenburg Window (Figure 1). Based on the COP features in Table 1, an identification of the common information needs in particular scenarios can specify the mechanisms for building a COP a more specific process. However, as long as the different organizations are characterized by different disciplines, tasks, goals, and working modes, the COP cannot guarantee that stakeholders will achieve a common situational understanding. These differences might result in a diverse operational understanding of the COP. For a successful outcome, the actors involved must have the same awareness of what is going on (Berggren and Johansson, 2010), and a comprehensive COP serves as a solid support for building a common situational understanding.

Table 1: Important features of a COP

1	Creation and maintenance of different levels of SA within the involved agencies.
2	Knowledge of each other`s operational modus, such as information needs, goals, capabilities, processes and resources.
3	Effective and time-specific communication of important static and dynamic environmental features, shared elements and common critical cues.
4	Harmonized terminology, both in vocabulary and software symbols.
5	Sharing useful comprehension of the current situation and actions/action planning important for the collaboration.
6	Follow a standardized framework for communication to avoid useless information and information overload.

METHODOLOGY

As there are limited references on the specific information requirements of multi-agency operations in relation to extreme weather, the people working in the investigated organizations are considered "knowledgeable agents" (Gioia et al., 2013). This term is used to address the unique insight of experts regarding their own working processes. Since this study seeks knowledge relating to these processes, a qualitative research approach was chosen. However, as the informants were individuals in a larger system, their answers may have been incomplete. Moreover, as the focus of this study is on specific information needs, it is important to note there seemed to be few procedures in the studied organizations that specified the information requirements in the selected scenarios. Therefore, qualitative interviews were conducted with twelve experts from first- responder agencies and municipalities. In addition, a survey was sent to three other organizations, all of which are characterized as support organizations because they are not responsible for handling the crisis (Table 2).

The answers from both the interviews and survey were categorized based on the selected scenarios and were further classified into information requirement categories using an inductive method. The classification was based on the informants' answers and not on universal definitions. For example, when an informant said, "*which area is affected by the forest fire*," this was classified into the information requirement category "location." Another example is that roads, power, and networks were classified under "critical infrastructure." Finally, the information requirements were compared, and the common requirements were determined and described (see Table 2). The informants were asked how they shared information in today's practice and what they characterized as the ideal sharing method. This was further discussed in light of the Gothenburg Window (Figure 1). The data from both interviews and survey were coded and analyzed in NVivo (QSRInternational).

Data collection

The data were collected through interviews with nine actors from the emergency management organizations and a supplementary survey with six additional experts (Table 2). The informants from the first-responder organizations were recruited by their leaders following a request from the author. The four emergency coordinators were contacted directly and agreed to participate. The interviews were conducted in the informants' workplace. Several of the informants from the first-responder agencies demonstrated their working process by means of a tour and gave an introduction of their information systems as well as how and when they were used. This gave a more holistic picture and resulted in the author's deeper understanding, in the interview situation, when an informant referenced a working process. In addition, I have had ten years' working experience as a medical emergency dispatcher, which also contributed to a mutual understanding.

Table 2: Respondents

Respondent Id	Organization	Role	Data Collection
1	Fire and Rescue Services	Emergency Dispatcher	Interview
2	Fire and Rescue Services	Shift Leader	Interview
3	Fire and Rescue Services	Professional Development	Survey
4	Police Services	Emergency Dispatcher	Interview
5	Police Services	Emergency Dispatcher	Interview
6	Medical Services	Head of Section, Acute Medical Communication Services	Interview
7	Medical Services	Professional Development in Acute Medical Communication Services	Survey
8	Municipality	Emergency Coordinator	Interview
9	Municipality	Emergency Coordinator	Interview
10	Municipality	Emergency Coordinator	Interview
11	Municipality	Emergency Coordinator	Interview
12	Municipality	Head of the Preparedness Section	Survey
13	The Ministry of Justice and Public Security	Director	Survey
14	The County Governor's Office	Assistant Director	Survey
15	The Civil Defence	Head of District	Survey

The interviews lasted between 45 minutes and one hour each and were based on a semi-structured interview guide. The guide consisted of open-ended questions, divided into the following four areas: (1) the informant's background, (2) human systems, (3) technological systems, and (4) building a COP and common situational understanding. A series of questions were asked during the interviews, with a special focus on the informants' working modes, such as the structures or procedures used to collect information on the emergency, whom to contact, with whom and how they share information, and their specific information requirements. In addition, the informants were asked about their experiences and opinions regarding the construction of a COP and the achievement of a common situational understanding. Therefore, the qualitative interviews were connected to complex events, using a forest fire scenario as an example. However, they also targeted the general aspects of operations in extreme weather and other operations. The main purpose was to learn about the organizations' processes for information sharing and discovery of specific information requirements as well as the informants' framework of meanings. This was in keeping with the issue of avoiding my assumptions to the greatest extent possible (Britten, 1995). During this study, I did gain experience at a C3 but did not possess the specific knowledge investigated in this study. Nevertheless, I have an insight into the domain. However, it is important to be aware of one's pre-knowledge and how this can affect interviews. Finally, the qualitative interviews were recorded and transcribed in detail. The texts were coded in NVivo and analyzed by the author.

In order to collect information requirements intended for extreme weather scenarios, experts in several emergency management organizations were contacted. These informants received a link to a survey with the scenario descriptions and were asked to write their information requirements in the specified fields. They were again contacted prior to receiving the link. As the respondents had direct contact with the author, the interactions can be regarded as mutual communication. The informants represented first responders as well as municipality and support organizations. The information requirements from the support organizations were collected in order to investigate the differences between their requirements and those of the key organizations. The information

requirements were listed and categorized based on data from the qualitative interviews.

RESULTS AND DISCUSSION

The specific information requirements identified were classified into eight categories. The reason for the categorization is that the different organizations need somewhat different details regarding the information requirements. For instance, the fire services require more elements on the terrain than others, and the medical services must know more details about the victims. Thus, the information needs of organizations require different levels of details. The information requirement categories are listed in Table 3, including an explanation of what each category entails, based on the data. Further, the "window report" structure was used to demonstrate how and with whom the information can be shared, as presented in Figure 3.

Information requirements

During the data collection, eight relevant information requirement (IR) categories for sharing were identified and classified into static and dynamic information (Table 3). The categories were not organized in prioritized order at this stage. Each information requirement category is presented below, including the basis for it. However, not all requirements were common for all support organizations. IR 3, 4, and 7 were not included in any of the responses from the support organizations. The reason might be that IR 4 (evacuation possibilities) and IR 7 (critical buildings) are closely related to the tactical level, while the support organizations are more interested in the information connected to the operational level. IR 3 (victims) was mainly the responsibility of "situation-owners." Nevertheless, further research on these "missing" information requirements might yield different results.

IR 1 concerns the possible scope and exact position of the important locations. This can be the coordination point for the operations leaders from first-responder agencies, a meeting place for operations units, and support organizations or representatives from the municipality. In particular, the organizations interviewed did not have access to the same GIS interface, and on occasion, they spent a considerable amount of time explaining locations to collaborative organizations. As an informant said, "*If we could see the positions in the map instead of describing (…) then you would know exactly where to go.* According to another, "*Now, everyone is searching for position (…) where it has happened, separately*." This non-sharing of information relating to position was specifically stated in the interviews and came out very clearly when it turned out that two of the first-responder agencies had the possibility of sending the GIS position to each other. Both organizations pointed to the major advantage of this feature and underlined its time-saving functionality. As one stated, "*It [shared position in GIS] saves us a lot of time when you don't have an exact address*." Such statements indicate that a common GIS interface would be beneficial for creating a COP concerning emergency locations. In fact, all the informants emphasized a common GIS interface for location sharing. Location information also concerns the type of terrain and topography of the area. To address the different needs related to this information, a scaling of the details on the map could solve the issue of information overload. This information is also important when operating with the impacts, or the mapping of the possible impacts, of the scenarios. Setting visible positions and lines in a GIS can improve strategic coordination between the actors involved.

IR 2 concerns critical infrastructure such as transportation systems, water supply, and telecommunications. One informant described how they coordinated the bus transportation in a storm scenario by using a real-time GIS solution: "*We knew a lot of trees would break (…) but the public transport must go on. We then called in the bus company, and they have a real-time view of all their busses. This was incredibly useful because when a tree fell over the road, the coordination of the bus could adapt to the situation*." In this case, the overview of the transport systems and access to information on obstacles enabled the organization to maintain its responsibility in a crisis situation. Critical infrastructure is also important for sharing information regarding different challenges in an area, and several of the informants highlighted the importance of mapping and taking early actions concerning weak groups, such as old, sick, and disabled people. Many people need electricity for medical reasons, home care, and special measures. While this is the responsibility of municipalities, in many scenarios, it might result in tasks that need to be solved by first responders. One informant illustrated the despair of not having the overview: "*In X scenario, 40,000–50,000 people had no electricity (…) and we don't know how many patients have received a COPD apparatus that needs to be refilled (…). How should we know this? They (the patients) are sitting and calling someone and worrying about the electricity being gone. So, this is just chaotic, so to speak*." This quote illustrates how the responsibility of municipalities fuses with that of first responders if the patients' condition worsens because of sustained power outages and if measures are not implemented in time.

IR 3 is important for several reasons. First, first responders must prepare medical treatments and search and rescue operations for victims, both in scope and under specific conditions. These are resource-demanding operations that require great effort from several stakeholders. Second, this is important information concerning

the evacuation process. Third, during disasters, an important step is to keep people informed. The extent of damage, perhaps especially when it comes to injuries, is of great interest to the public.

IR 4 is connected to IR 3, but it also concerns the number of people, including victims and next of kin. In addition, the need for evacuation is not exclusively for injured people but also involves situations where people need to evacuate from their homes. IR 4 also considers the need for staff in the evacuation situation. IR 1 relates to this information requirement in the sense that the location of the evacuation spot or center must be determined.

IR 5 concerns resources. The informants talked about resources in different terms. For instance, resources can be the operations units of the first responders involved. Another side of resources has to do with different supplies, aid, and support that can be used when needed. This illustrates the importance of the fourth COP feature concerning a harmonized terminology, whereby actors need to be knowledgeable about the terms used by each other and what the concepts entail. An overview of available resources can help organizations mobilize measures while also considering resource adequacy vis-à-vis the situation at hand. One informant explained resources like this: "*Available resources, who, what, where? Are there other resources besides ours we can take advantage of? That's the first thing*."

IR 6 is crucial for planning the next steps of the operation. For instance, wind direction, rain fall, and wind speed are important pieces of information in preventing and handling the consequences of extreme weather.

IR 7 involves important buildings, both in terms of handling the operation and preventing damage. Examples include nursing homes, hospitals, and evacuation centers, all of which are connected to IR 4.

IR 8 is an interconnected information requirement, which concerns weather trend (IR 6), possible victims (IR 3), and resources (IR 5). In addition, the requirement covers other projections on how the situation might develop. According to an informant, "*How we comprehend the situation, if it's a threatening situation and it poses a danger for others involved*." In the "window report" structure, IR 8 can be seen as an information requirement in itself because it illustrates some information that needs to be shared. However, this information requirement can also be seen as an indication of the need for analyses of IR 1–7 to achieve level 2 and 2 SA, which is more suggestive of a process for achieving common situational understanding.

Table 3: Common Information Requirement Categories

Information requirement category		Description	Static/dynamic information
IR 1	Location	Exact area for coordination point or meeting place. In addition, topography, terrain and exact scope.	Static
IR 2	Critical infrastructure	Essential assets such as transportation systems, water supply, electricity, and telecommunications	Static and dynamic
IR 3	Information on possible victims	Whether there are people involved who are, or are at risk of being, injured, threatened, or dead because of the situation; vulnerable groups that might be in the affected area	Dynamic
IR 4	Evacuation possibilities	Whether evacuation is required now or in the future, where the possibilities are and the approximate number of people	Dynamic
IR 5	Resources	All operations units from the first responders involved, the collaborative organizations' resources, such as power generators and water supply. Other available resources, such as tractors and buses	Dynamic
IR 6	Weather forecast	Current weather at affected locations and weather forecasts	Dynamic

IR 7	Critical buildings	Hospitals, evacuation center, and schools	Static
IR 8	Situational development	Expert assessment on how the situation can develop	Dynamic

One obvious finding to emerge from the analysis of the different information requirements is that it is not possible to operate with a single COP, as it must consider all the organizations involved and their need for an operational picture. The information overload issue would be a component, in addition to the fact that the consideration of all information needs would require a COP that is difficult to build and maintain. The informants' responses clearly demonstrate that their need for specific information is related to agency-specific tasks and goals. However, there are many common features in the identified information requirements (demonstrated in the categorization), which should be the foundation for sharing common information and for building the COP.

Example of an information sharing structure

Although the actors involved in multi-agency operations have some agency-specific goals, collaboration is a critical success factor in the achievement of common goals. In order for this collaboration to be as successful as possible, it is crucial that the common information requirements are shared with the relevant stakeholders and not remain within the agencies or individual actors (Sorensen and Stanton, 2016). A study on SA for building a fire emergency response demonstrated the importance of information collection in SA building, especially information items from the emergency site (Li et al., 2014). Thus, the "window report" structure should not be limited to a fraction of the organizations involved; it should include all relevant levels of cross-sectional collaboration. Today, the structure is mainly designed for information sharing between first responders and is perceived as a well-known structure for information sharing where elements are distributed within the inter-agency network—appearing as an effective and prioritized structure. During the data collection for this paper, several of the actors refers to the window structure when asked about how they build a COP, e.g.: *"I really like what we call "window report" in the common call group, the first actors on the scene – what do they observe? This is important for us in the CCC because we do not have any visual picture of the situation".* Such structure of information sharing among the relevant agencies can therefore be seen as the foundation of the COP. The use of an information sharing structure to build a COP can enable the expansion of the scope of information receivers in order to enhance the SA of the organizations involved.

One can argue that level 1 SA represents the information collection and might be the essence of the "window report." The exception could be *Trend* on occasions where the status quo is escalating or calming down, and the distributor of the "window report" must understand the information and form cognitive patterns based on professional experience. This would indicate level 2 SA, and some cases could be associated as level 3 SA if they are deemed relevant in reporting a projection, i.e., a future status report. *Place*, *Direction*, and *Resources* require objective information that reflects actors' first impressions. SA levels do not represent the actual manner of reporting but, rather, the specific situational information being reported. One must consider that SA is not the performance or action itself (Wickens, 2008), thus, the "window report" relies on external structures or procedures, in addition to the actors' perception of the environment. This is important because even if the stakeholders hold relevant information on the situation, it is not necessarily shared with the collaborating organizations.

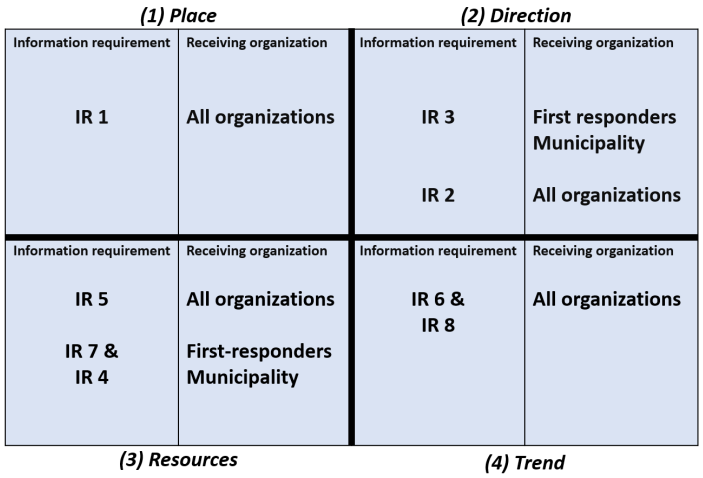

Figure 3: The Gothenburg Window as structure for sharing common information

Although this study was limited to identifying information requirements and did not address the prioritized order of the elements in the reporting structure, the *Trend* and *Resources* sections in the Gothenburg Window (Figure 1) have switched places in this paper's suggestion of the "window report" structure (Figure 3). This is based on the informants' answers regarding the information needs, where the information requirements for *Resources* were generally prioritized over those for *Trend.* However, further research on such a "window report"

structure and the prioritized order for the information requirements is needed.

Based on the data from the interviews, first responders are familiar with the "window report" structure, which arguably depicts a relevant procedure for information sharing. Therefore, it could be valuable to discuss what features of *Place*, *Direction*, *Trend*, and *Resources* can be linked to the COP concept as well as important COP features (Table 2). Further, the common information requirement categories can be placed in the window and serve as a structure indicating what information must be shared and to whom (Figure 3), as a conceptual structure for the information presentation. Since the second and fourth COP features concern knowledge of the other collaborative organizations and a univocal terminology, respectively, they involve training, preparation, and relationship building and do not include information that is directly a part of the "window report" structure. However, features 1, 3, 5, and 6 have a clear relationship with the structure's content. *Place* is connected to sharing critical location information, for instance, the exact position of the emergency event, the meeting point, and other elements connected to IR 1 (Table 2). This is the first square in the window and must be accurately communicated, with no room for errors. Incorrectly communicated information regarding location can have critical consequences, such as resources being delayed. An exact position in a common GIS would obviously be effective. *Direction* involves SA because it is a short description of the situation. Because a "window report" is a first-impression description, the *Direction* should mainly consist of level 1 SA elements, whereby the actor describes the situation in an objective way and distributes the elements in the environment to the collaborative organizations. This could relate to victims (IR 3), information about whom should be presented in an objective manner, such as whether or not there are injuries, since there are several pitfalls in projecting the status of patients, and injured people must be evaluated by medical personnel. Critical infrastructure (IR 2) represents issues concerning closed roads or other dynamics of the environment that could impact the operation and should be presented in the *Direction* square. In the *Resources* square, the information requirements 5, 7, and 4 should be presented: first, all available resources; second, whether critical buildings are destroyed or threatened; and third, the possibilities for evacuating the area. The last square in the window is *Trend*, where information requirements 6 and 8 should be presented. These requirements are interconnected in the sense that the weather forecast needs to be shared, and the consequences need to be predicted. IR 8 can also be interpreted as an analysis of the previous information requirements.

There are implications regarding how to handle the kind of information that might be provided by the COP in this case. New available information and insights are likely to emerge into more alternatives in the working processes, both internal and collaborative. It is beyond the scope of this study to discuss all working processes, but how information sharing is performed is likely to be affected. In today's practice, information sharing processes in Norway are mainly verbally performed in the Public Safety Network and by telephone. Some of the responders mentioned e-mail as a possible way of sharing information, for instance, on one occasion where a fire and rescue C3 was overloaded by incoming inquiries, a collaborative organization communicated with them by e-mail. However, the COP concept indicates "a picture" of the situation, which makes it seem more like an object. In this sense, the organizations would benefit from a common GIS interface, where the information requirements are visualized and scaled by different techniques. The static information must be displayed in some sense, and the dynamic must be inserted. However, some of the content of the information requirements, such as IR 8, might be communicated verbally because it concerns the common situational understanding. The COP is an important foundation for this understanding, but the common situational understanding requires bidirectional communication to clear up misunderstanding as well as the possibility for additional questions.

CONCLUSION

This study has identified eight information requirement categories, which are necessary for building a COP when the first-responder agencies and municipalities tackle extreme weather scenarios. However, it is important to emphasize that a single COP is not sufficient to provide a holistic operational picture for all the agencies involved; rather, it is a selection of the relevant dynamic and static information that will contribute toward building a COP. Based on the combination of the information requirement categories identified, the COP concept as an object is described in Table 1, along with the important features. One can argue that the COP is the result of preparation and a structured working methodology. This preparation consists of knowledge regarding each other's operational modes and harmonized terminology and the pre-knowledge on common information requirements that needs to be shared during an operation. The working methodology, in this case, consists of how to share the relevant information. This paper discusses the "window report" structure as an example of how to effectively share both static and dynamic operational information and make the information sharing process more integrated in the working processes. However, one must acknowledge that the working processes need to forge a way in which information provided by the COP is handled and used efficiently.

Predefining the information requirement categories for the organizations in the different contexts might facilitate the inclusion of a COP perspective at the strategic level of emergency management. Today, the information

must be shared verbally in the Public Safety Network, but a common GIS interface seems to be the way forward. The "window report" structure would in this case serve as a template for what areas of information need to be shared, which information categories and to whom, in different types of crisis.

Given the small sample size of this study, the findings presented must be validated by users, and further research should focus on developing a conceptual model on how to build a COP in multi-agency operations handling extreme weather events. Finally, as the study is limited to Norwegian and Swedish practice, further research could compare these results with structures used in other countries.

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From common operational picture to common situational understanding: An analysis based on practitioner perspectives

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ABSTRACT

The concepts of Situational Awareness (SA) and Common Operational Picture (COP) are closely related and well-acknowledged to be crucial factors for effective emergency management. In multi-agency operations, such as extreme weather events, the involved first responders manage the event with different mandates, objectives, and tools which can make it challenging to build a COP. Effective collaboration requires a common situational understanding, based on knowledge about each other's responsibilities and tasks, mutual respect and trust, as well as common communication tools for emergency communication and information sharing. This paper argues that the COP serves as a basis for deciding on further action, and thus represents a first stage in the process of establishing common situational understanding among the involved actors. The empirical basis for the study includes interviews with Norwegian emergency management stakeholders, analysis of audio-logs, and review of public documents. Based on the analysis we present a framework comprising activities and processes involved in establishing a COP as a basis for common situational understanding.

1. Introduction

The importance of situational awareness (SA) for effective emergency management is well acknowledged in research and practice (Blandford & Wong, 2004). Especially in complex operations involving several agencies and disciplines, a common situational awareness provides a foundation for the actors' understanding of the environment. Endsley (1995) formally defines SA as "the perception of elements in the environment within a volume of time and space; comprehension of their meaning; and projection of their status in the near future" and more unformally as "knowing what is going on." (p. 287). Endsley s definition involves three hierarchical levels of SA comprising (1) the perceptual level: the detection, recognition, and identification of the elements in a specific situation; (2) the comprehension level: an understanding of the current state based on the information from the perceptual level in terms of what the different elements mean in relation to the agent's professional goals; and (3) the projection level: where the actor makes interpretations concerning the direction of the situation based on the prior levels and professional knowledge (Endsley, 1995; Imoussaten, Montmain, & Mauris, 2014).

The concept of common operational picture (COP) is closely related to SA. Originating from the military context, a COP is commonly viewed as a "centralized information display system" (Hwang and Yoon, 2020), presenting situational and operational information from various sources relevant to the involved stakeholders. Yet, as will be discussed in this article, there exist different perspectives on the term. Further, the COP only serves as a basis for deciding on further actions, thus representing a first stage in the process of establishing a common situational understanding among the involved actors. This understanding encompasses the involved actors perceptions, actions, and decision-making processes that facilitate effective collaboration. Table 1 presents the different characterizations of COP identified in the literature.

In multi-agency operations, the involved first responders are guided by different mandates and objectives that can make collaboration challenging (Karagiannis & Synolakis, 2016). In complex scenarios, such as extreme weather events, the emergency management operations extend beyond the first responders (police, fire, and health services) to also include local government (e.g. municipal emergency management) and infrastructure service providers (e.g. electricity providers, transport authorities). All of these organizations must work towards common goals (Scholtens, 2008), making the collaboration process even more complex. In this paper, we adopt the term "community of responders" (Valecha, Rao, Upadhyaya, & Sharman, 2019), defined as "a group of emergency personnel who share a set of activities, and who interact to

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Table 1
Characterizations of COP.

COP characterization	Example references
(1) The COP can be a situation awareness system which refers to knowledge management systems for SA and decision-making.	McNeese, Pfaff, Connors, Obieta, Terrell, and Friedenberg (2006)
(2) The term COP extends prior research on large group displays to describe a visual representation of tactical, operational, and strategic information intended to generate situational awareness.	Hwang and Yoon (2020)
(3) The COP as a continuously maintained description of the situation and operational environment built from the received information and the conclusions based on it.	Norri-Sederholm, Joensuu, and Huhtinen (2017)
(4) COP incorporates information that enables situational information to be produced, visualized, and presented in such a way that all information is available to all the actors involved in the crisis response in real-time.	Luokkala, Nikander, Korpi, Virrantaus, and Torkki (2017)
(5) COP as a mental model of how the system works, guiding the application of a safety management system in everyday practice.	Aneziris, Nivolianitou, Konstandinidou, Mavridis, and Plot (2017)
(6) COP as a display of relevant operational information, such as positions, infrastructure, and different resources.	Karagiannis and Synolakis (2016)
(7) The COP is created by an actor and consists of a selection of important parts of the available information, in the form of descriptions and predictions of what is going on, and related information as e.g. resources, actions, prognosis, and perceptions.	Borglund (2017)
(8) A COP is a centralized information display system which is designed to establish team SA by presenting information that is gathered from various subsystems.	Baber, Stanton, Atkinson, McMaster, and Houghton (2013)

achieve shared objectives, and to maintain their community" (Fischer and Benion, 2005, cited in Valecha et al., 2019, p. 33). Further, a community of responders represents an informal network of emergency practitioners who share expertise and practical advice at different levels (Valecha et al., 2019).

The community of responders includes multiple decision-making command and control centers (C3) (Karagiannis & Synolakis, 2016) and different internal structures for individual and team decision-making within each agency (Smith & Dowell, 2000). In the acute phase of an operation, the first responders generally acts from a monodisciplinary perspective, having to cope with their own tasks and also not wanting to tread on other agents' territory (Scholtens, 2008). The internal structures provide stability for the responders within each agency, and teams are formed by their defined processes for communication and action. This stability facilitates required knowledge sharing for internal decision-making and actions in each agency, in time-critical situations (Luokkala & Virrantaus, 2014). However, for multi-agency collaboration to be effective several additional factors need to be in place, such as knowledge about each other's responsibilities and tasks, mutual respect and trust, as well as common communication tools for emergency communication and information sharing (Steen-Tveit, Radianti, & Munkvold, 2020). Previous research has documented problems with information sharing processes in a community of responders during multi-agency operations, related to heterogeneous information needs, different communication processes, and information overload due to lack of filtering of irrelevant information (Bharosa, Lee, & Janssen, 2010, etc.; Comfort, 2007; Wolbers & Boersma, 2013, etc.).

The assumption of a shared mental model (SMM) is well known in previous studies on high-performance human teams (Bolstad & Endsley, 1999; Cannon-Bowers, Salas, & Converse, 1993; Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). The SMM concept involves that the actors in different organizations will improve their performance if they share an understanding of their own and other involved team members' operational tasks (Jonker, Van Riemsdijk, Vermeulen, & Den Helder, 2010). Further, in time-critical operations, the responders need to act quickly upon the available information, and the Recognition-Primed Decision (RPD) model (Klein & Crandall, 1996) offers an analytical process to reach a decision. The model describes how experienced actors make efficient decisions in stressful conditions, and how they reduce information overload by focusing on critical cues and factors influencing the situation development. When these causal factors are identified and assessed together with goals, and using mental simulation to exclude eventual pitfalls, the right decisions are more likely to be made (Klein et al., 1993). Taking the steps in the RPD model into consideration when developing procedures related to different scenarios can guide the user to consider different solutions than the first that comes to their mind based on previous patterns, time pressure, or uncertainties. It is important to evaluate the different options that occur in various situations, especially for novices, but also for avoiding biases for experienced actors. The paper draws upon the SMM and RPD models for the analysis of the results.

While several studies have contributed to developing a conceptual understanding of COP (e.g. Hwang and Yoon, 2020; Luokkala et al., 2017), there is still limited research on how emergency stakeholders communicate and interact in the process of establishing a COP. Based on a study of current practice among emergency management professionals in Norway, this paper provides an analysis of the role of COP as a baseline for developing common situational understanding in a community of responders. The analysis includes the current and potential further use of information systems support, including geospatial services and the Norwegian Public Safety Network (i.e., radio communication) used for inter-agency communication. The empirical basis for the study includes interviews with 16 Norwegian emergency management stakeholders, analysis of audio-logs, and review of public documents. Based on the analysis we present a framework comprising the activities and processes involved in establishing a COP as a basis for common situational understanding. The framework contributes to clarify the distinction between the concepts of COP and common situational understanding, and outlines the steps in how to get from one to the other.

The paper is structured as follows. Section 2 provides an overview of previous research on the concept of COP related to common situational understanding, followed by a presentation of the methods for data collection and analysis in section 3. Section 4 presents the results of the analysis. First, the current practice for inter-agency communication and collaboration in emergency management in Norway is described. Second, the results from the interviews and audio-log analysis are presented. In section 5 the results are discussed in light of important features of a COP and elaborated with the theory of SMM and the RPD model for understanding how the framework can support the community of responders to achieve common situational understanding. Section 6 concludes the paper and presents implications for further research and practice.

2. Related research

In this section, we review related research on the concepts of common operational picture (COP), shared mental models (SMM), and the RPD model.

2.1. Common operational picture

The COP concept arises from the military context, where the COP is elicited from the commanders' SA when working in a C3. The C3 commanders are consulting and supporting decision-making in the operation

carried out by soldiers on-site by integrating relevant technologies for enhancing their SA (Kumsap, Mungkung, Amatacheewa, & Thanasomboon, 2018). There is no univocal definition of the COP term (Wolbers & Boersma, 2013), and different perspectives exist on COP as a process, product, or operating environment (Copeland, 2008). Table 1 presents the different characterizations of COP identified in the literature.

There are two types of characterizations of COP that seem to be most prevalent in the literature: whereas the first focuses on the opportunities for information sharing (COP characterizations 1,2,5,6,8 in Table 1), the second concerns the requirements for developing common situational understanding (COP characterizations 3,4,7 in Table 1) (Giaoutzi and Scholten, 2017). The sources of information for the COP include on-site observations, static information collected from geographical information systems (GIS) and other relevant resources, and dynamic information from different sensors and mobile systems (Bunker, Levine, & Woody, 2015).

To achieve effective collaboration and information sharing in different settings, the organizations involved need to know each other's information needs, goals and expectations, professional culture, capabilities, and procedures (Norri-Sederholm et al., 2017). A recent study examined the community of responders' shared information requirements for managing extreme weather events (Steen-Tveit, 2020). The results indicate that it is not possible to operate with a single COP, as it must consider the specific information needs of all organizations involved in addition to the shared elements. Besides the challenge of information overload, a COP displaying all information needs would also be difficult to build and maintain.

The perspective of COP as an objective picture or "information warehouse" emphasizes the importance of common situational understanding because of the heterogeneous information needs and differences in mutual knowledge, operational understanding, and assumptions between the community of responders. Thus, the COP must be flexible and provide access to particular SA needs for the involved agencies for them to be able to display their 'common relevant operational picture' (Baber et al., 2013) and at the same time clearly visualize the important shared operational and situational elements for the overall picture. This overview and access can enable the agencies to collaborate in the planning and execution of comprehensive tactical operations (Giaoutzi and Scholten, 2017).

McNeese et al. (2006) describe that the COP can function as a structure for available information to be collectively transformed by the actors into knowledge. The structure will capture and portray the historical and emergent state of entities, events, and conditions relevant to the situation. Further, the structure will capture and relay interrelationships so far as they impact plans, decisions, and interactions. Commenting on sense-making McNeese et al (2006, p 468) argues: *"Much of the structure is coupled with sense-making, knowledge management, and information-seeking needs as they unfold in emerging situations wherein data is transformed into information, and information is inducted collectively into knowledge."* However, sense-making and knowledge management takes place through human interactions between team members that together make sense of the situations, negotiation meanings, intentions, and plans. Thus, the COP must empathize systems for negotiation of the actors' different views. It is crucial that the stakeholders have the ability to negotiate a substitute picture of the situation by using shared protocols for communication and procedures (Bunker et al., 2015).

Common situational understanding concerns additional and more abstract information, for instance, the human capability to quickly and accurately share a diagnosis of unexpected behaviors and problems (Arciszewski & De Greef, 2011). The ideal COP should utilize tools for selecting and combining situational information for creating narratives supporting the users to achieve all three levels of SA (Luokkala et al., 2017) and human–machine interface design for exposing the organizations ' operational procedures in a meaningful way (Hwang & Yoon, 2020). In multi-agency emergency management, the people working together form a socio-technical system, involving a combination of human–human and human–computer interactions. The involved actors each have their own knowledge and without sufficient communication between the actors, each participant will create his/her own mental representation from the perceived information (Lelardeux, Panzoli, Lubrano, Minville, Lagarrigue, & Jessel, 2017). As the COP represents operational information but only tells part of the story, the actors also need to interact by verbal messages in co-developing a situational understanding based on the operational knowledge. Situational understanding can be related to SA levels 2 and 3 because it both involves a comprehension of the current situation and the ability to project future status. In other words, while a COP provides the "what," the situational understanding is the answer to "so what?" and these answers need to be understood by the community of responders during the operation for successful collaboration.

2.2. Shared mental models

Previous studies on high-performance human teams show that some characteristics seem to be important. Firstly, they can often anticipate other team members' needs. Secondly, they can proactively help each other performing their tasks (Yen, Fan, Sun, Hanratty, & Dumer, 2006). For this to be in place, the involved actors must have a shared mental representation that involves the distributed decision-making processes among the community of responders (Smith & Dowell, 2000), which in the literature is referred to as shared mental models (SMM) (Jonker et al., 2010). SMM enable the involved actors to predict other actors' needs for performing tasks and to anticipate their actions in order to adjust their own behavior accordingly (Cannon-Bowers et al., 1993). Their individual mental models (MM) explain and predict the individual's surroundings (Rouse & Morris, 1986), and these MM assemble and become an SMM when the involved actors are sharing and learning about each other's MM content, i.e., goals, tasks, needs, procedures, etc. The scope of SMM involves common ontology and knowledge, shared plans and structures, and mutual trust (Yen et al., 2006). While identical MM is utopic, the community of responders must strive for adaptable models that can be a guide to common expectations (Cannon-Bowers et al., 1993). In most organizational settings, and especially in the context of emergency management, training is essential for the development and refinement of SMM (Klimoski & Mohammed, 1994). Singh, Sonenberg, and Miller (2016) consider two components of SMM to be important for common training: intentions e.g., goals and world knowledge e.g., beliefs. In training situations, evaluation can provide opportunities to test the involved organizations' effectiveness (Berlin & Carlström, 2015), and there are several methods for measuring SMM in training situations (DeChurch & Mesmer-Magnus, 2010; Harbers, Riemsdijk, & Jonker, 2012, etc.). The question then is, what should the SMM include? In many scenarios, there is a lack of knowledge regarding specific information needs in multi-agency collaborative operations (Munkvold, Radianti, Rød, Opach, Snaprud, Pilemalm, & Bunker, 2019). Thus, knowledge on various information requirements for how to understand (world knowledge) and handle (intentions) this information for achieving common goals constitutes a reasonable foundation for exercises to develop SMM. Crisis management is a continually changing process as the situation develops and the community of responders must communicate with messages that are indicative of the world knowledge and intentions (Singh et al., 2016). Establishing SMM is here crucial for efficient communication (Hwang & Yoon, 2020) and preventing information overload, which is a problem especially in information visualization (Ellis & Dix, 2007).

2.3. Recognition-Primed decision (RPD) model

Managing new and unknown events is a challenge because humans tend to seek explanations based on past experiences that give a sense of

control. These explanations turn unknown situations into known – and therefore become "true", but in many cases they can represent serious misjudgments (Weick & Sutcliffe, 2015).

Researchers (e.g Stanovich and West, 2000; Evans, 2003; Kahneman, 2011) have divided the human mental process into two systems which both include features that impact on human decision-making processes. System one is the unconscious mind; it is fast, emotional, and based on previous experience (e.g. instincts). This includes tactical knowledge, and most decisions are based on system one because it saves energy as it does not demand extensive mental effort. However, as this easy way of doing decision-making is biased of previous experiences and prone to error (Kahneman, 2011), there is a need for a second system to prevent possible mistakes. System two thus is more deliberate and logical, but also demands more energy (Luokkala & Virrantaus, 2014). System two monitors system one and might prevent poor decisions made based on biases from previous experiences. Also, it enables comparison of different alternatives, and makes the decisions more adapted to the specific situation. While actors with long experience tend to be able to identify important information faster, their brain tries to reduce the use of system 2, such as for all humans, they want to select the first option that comes to their mind. The Recognition-Primed Decision (RPD) model (Klein, 2008) demonstrates how experts make decisions based on the two mind systems. Experienced actors in operational settings make decisions based on two processes: (1) situation assessment which can be related to system one, and (2) mental simulation which can be related to system two (Luokkala & Virrantaus, 2014). Thus, decision-making in time-demanding operative settings requires both system one and two.

3. Methods

The empirical basis for this study includes interviews of 16 Norwegian emergency management stakeholders, including representatives from first responder agencies, four municipalities, the Norwegian Public Safety Network (NPSN), and a system vendor for emergency management GIS. All interviews were conducted on-site at the representatives' workplace, except a group interview with NPSN managers that was conducted on skype (due to the COVID-19 pandemic). Further, the audio logs from an emergency exercise were analyzed to identify how the current verbal information sharing influences the COP. Finally, analysis of relevant public documents such as evaluation reports from recent emergency events supplemented the interview data. A summary of the data collection is presented in Table 2 and further elaborated in this section.

Table 2
Summary of data collection.

Methods for data collection	Interviewees/Data sources	Purpose
Semi-structured interviews	12 emergency management stakeholders	Investigate current practices from professional actors' standpoint, and learn what kind of features they envision as useful for building a COP and common situational understanding.
	System vendor	Get a vendor' perspective of today's' possibilities, current challenges, and future possibilities for building a COP and common situational understanding.
Online group interview	3 managers from NPSN	Collect insight on the current state of NPSN use.
Audio-logs	4,25 h from a common call group in NPSN	Analyze verbal information exchange among first responders
Document review	21 public documents	Identify current emergency management practice in Norway, and evaluation of real events.

3.1. Interviews with emergency management stakeholders

Table 3 presents an overview of the interviewees. The interviews were conducted based on a semi-structured interview guide with open questions. The interview guide was divided into themes regarding the stakeholders' process to build common situational understanding in their organization; this included how they prepare for handling crises, their current knowledge on other stakeholders' information needs, terminology, and what constitutes a COP and common situational understanding. The questions were related to a forest fire scenario; however, the answers could also be related to other scenarios.

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For the system vendor, the interview guide covered the different GIS features in use by first responder agencies and future possibilities. Also, opportunities and capabilities for collaboration and information sharing within the different system were mapped. Since the NPSN is the main communication platform for the first responder services, interviews with managers in NPSN were conducted to get clarity on the status of different organizations' use of the NPSN.

The interviews lasted between 45 and 75 min. Except for the online group interview with NSPN, all interviews were recorded and transcribed in full and analyzed in NVivo (QSRInternational). For the online interview, detailed notes were taken during the meeting. Since these interviews followed another interview guide, the answers were not included in the analysis in NVivo.

3.3. Audio-log analysis

The first responders in Norway are using the NPSN as a common platform for collaborative communication (see description in Section 4.1). The data from the audio-logs consists of 4,25 h of collaborative

Table 3
Overview of interviewees.

Interviewee #	Organization	Role
1	Fire and Rescue Services	Emergency Dispatcher
2	Fire and Rescue Services	Emergency Dispatcher
3	Fire and Rescue Services	Shift Leader
4	Fire and Rescue Services	Firefighter, an incident leader on emergency sites
5	Police Services	Emergency Dispatcher
6	Police Services	Emergency Dispatcher
7	Police Services	Emergency Dispatcher
8	Medical Services	Head of Section, Acute Medical Communication Services
9	Municipality	Emergency Coordinator
10	Municipality	Emergency Coordinator
11	Municipality	Emergency Coordinator
12	Municipality	Emergency Coordinator
13	System Vendor	System Developer
14	NPSN	Manager
15	NPSN	Manager
16	NPSN	Manager

communication in a call group reserved only for first responders (BAPS, fire-police-acute medicine cooperation) during a large scale regional multi-agency exercise where the scenario was an act of terror. The total number of messages analyzed was 135. The audio-log messages were transcribed and ordered in Excel according to the origin and recipient of the messages. The audio tracks reveal the actual timeline for both active communication and silence. Further, the content of the messages was reviewed to identify examples of how verbal information sharing of geospatial information supported the development of a COP. Further, the messages were categorized into 6 main categories based on the content. The categorization was inductive and was developed gradually through classification and reclassification based on the content of the messages. This resulted in the following categories: (1) Information on emergency events; (2) Action/action planning, involves location; (3) Communication different on locations, e.g. where is the incident, where are the resources, meeting place, etc (4); Request for various resources, can also be related to a specific area/location (5); Situation reports; (6) Contacting/confirming/request of information.

3.4. Document review

Several national guidelines, governmental white papers, and reports such as evaluations of real events were reviewed to gain an understanding of emergency management practice in Norway at different levels, and of how well current regulations, procedures, and work processes function during real emergency events.

4. Results

This section presents the results of our data collection. We first give an overview of the Norwegian emergency management practice for inter-agency communication and collaboration, including the newly established routines for the common use of the Norwegian Public Safety Network for simultaneous alert of the first responders. Then we summarize the emergency management professionals' experience from establishing COP and situational understanding and their views on how to improve on this.

4.1. Emergency management practice in Norway

The Norwegian Emergency Response Services comprise a multi-agency collaboration between several organizations from the government, voluntary and private organizations (Ministry of Justice and Public Security, 2008). The first responder agencies (police, emergency medical services, and the fire and rescue services) are the main stakeholders when handling an acute crisis, both for agency-specific and multi-agency operations. These first responder agencies each have their individual Command and Control Centres (C3) with different structures, working processes, and technological tools that are not well integrated. They also have different emergency phone numbers (110, 112, and 113), however, the different systems include a function to easily route the calls between the centers. In all operations, the main goal for the first responder agencies is saving lives, regardless of their distinct roles which are determined by agency, rank, and type of incident (National Police Directorate, 2011; Smith & Dowell, 2000). To ensure an efficient information sharing process between the three agencies in specific scenarios, Norway implemented a national triple-alert routine in 2019 (Norwegian Directorate for Health, 2019). This was a direct measure after an incident on the Valdres express bus in Årdal, Norway, 2013, where three people were killed in what was first perceived as a traffic accident, but actually was an act of terror (DSB, 2014). The incident evaluation revealed poor information sharing that had a considerable impact on the collaboration between the first responders. The triple-alert routine consists of a tool for inquiry and action covering nine scenarios (bomb threat, fire in a building, acute pollution, tunnel accident, ongoing life-threatening violence, a person in the water, accident at sea, avalanche, and traffic accident) and describes when and how triple-alert between the first responders should be initiated and implemented. When the incident requires more resources, other relevant organizations, such as voluntary organizations and the affected municipality/-ies, may be contacted. However, these organizations are not included in the triple-alert routine. The triple-alert routine has several advantages such as simultaneous notification of first responders and mobilisation of required resources, securing equal information for all at the same time, and giving the involved dispatchers the opportunity to ask questions and provid advice and guidance. Fig. 1 presents an overview of the triple-alert routine, structured into parts and using color codes.

The idea of the triple-alert routine is the ability to simultaneously receive information and to support understanding of each other's needs, limits, and possibilities. There exist no similar collaboration routines for other contexts, neither when it comes to additional organizations or scenarios. However, after the terrorist attack on 22nd July 2011, Norway implemented an additional core principle for emergency preparedness and response that applies to the capability to collaborate between the response organizations. Implied in this principle is an increased focus on effective information sharing to support a common situational understanding.

An important tool for supporting collaboration is the Norwegian Public Safety Network (NPSN) implemented in 2015, which is a common platform for secure collaborative communication between all organizations involved in emergency management (National Police Directorate, 2018). This network enables the users to communicate in different call groups across agencies and geographical areas based on the communication patterns within the community of responders. The NPSN is a key tool in the triple-alert routine and the handling of other collaborative events for the first responders. The common call group for first responders (BAPS) is frequently used during multi-agency operations for requests, situation reports, updates, and to build common understanding (Steen-Tveit et al., 2020). Several other emergency management services such as voluntary organizations, state actors, municipalities, and industrial safety organizations can use the NSPN in specified call groups (DSB, 2019) The Norwegian Government stated in 2014 that in addition to the first responders as the core users, all organizations that handle crises must have the possibility to use NPSN (DSB, 2019). In practice, this means that these additional organizations must apply for access, which also involves a fee. According to the provider of NPSN, while many of these organizations have access today, the actual adoption and use is varying. For example, in counties where they have a focus on emergency preparedness, generally more municipalities have applied and gained access to the NPSN. Also, some organizations also not consider themselves as an operative part of emergency events. According to a user survey, 75% agree that the NPSN has enhanced the efficiency of crisis communication (DSB, 2017, p. 6). However, as long as some of the organizations collaborating with the first responders are not using the NPSN they are excluded from the common call groups, and thus need to communicate with other tools such as telephone and e-mail. The challenges arising from this are illustrated in the evaluation report from the management of the Viking Sky cruise ship accident outside the coast of Norway in 2019 (DSB, 2020). The lack of access to NPSN (i.e. not being implemented in the organization) for several of the stakeholders in the crisis operation was found to be challenging, and many of the involved actors argued for the need for broader access to the NPSN to secure enhanced communication flow. This included all the affected municipalities, who expressed this as a missing possibility in the aftermath. The evaluation documented a widespread perception among the involved actors that the communication during the incident was deficient, and that it was challenging to establish a COP. Among other things, this was related to the status of passengers that were evacuated by helicopter and brought to the reception point. Also, the police and health services lacked information on different aspects of the maritime rescue operation and the situation onboard the cruise ship.

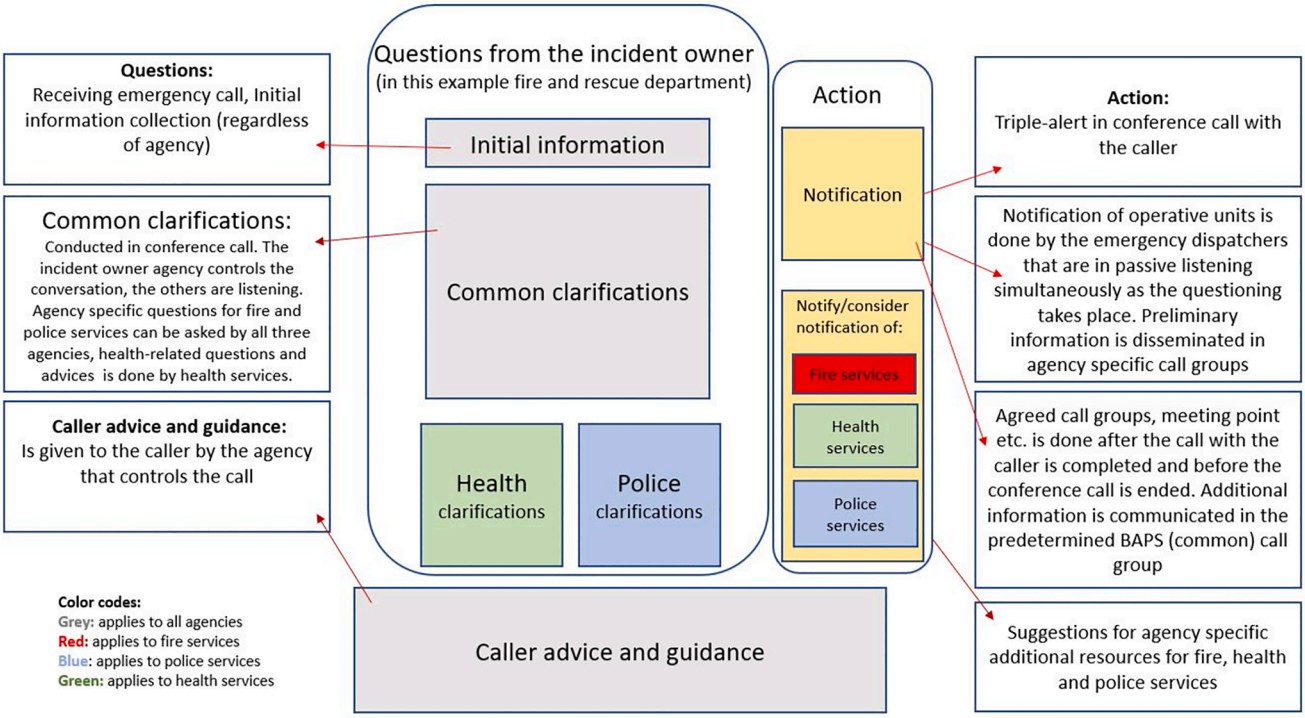

Fig. 1. Triple-alert routine for Norwegian emergency response. .
Adapted from Nakos.no (2018)

4.2. *Interviews with emergency management stakeholders*

This section summarises the findings from the interviews. The answers include both current practices/tools and suggested features for possible future solutions.

4.2.1. *Knowledge of own and collaborating organizations*

Overall, the respondents report having a good overview of their own organization's information needs and goals. They also expressed that they were satisfied with their training and overview of procedures. However, they all felt that they needed more knowledge of their collaborating organizations' information needs and goals in different contexts. As one of the responders pointed out: *"If I knew what the others* [members of other organizations] *needed, I believe we would have had an even better collaboration" (Emergency coordinator, Municipality),* and if they had more knowledge on each other's mindset "*then we would know what they want, and it would be much easier to understand and accept.*"(-Emergency Dispatcher, Police services). Another respondent explained his/her knowledge of other organizations' decision-making procedures like this: *"I have no idea. No, but when you talk to them, you make assumptions, but again, that could be rather dangerous."* (Emergency Dispatcher, Police services)

Common training was pointed to as important to improve this knowledge: "*We make scenarios and discuss with representatives from different agencies on how we handle things, that is fruitful because then we see that we think differently (…) we must sit together more often so that we learn to understand each other."* (Emergency coordinator, Municipality)

The interviews identified significant differences within the various organizations when it came to learning arenas, exercises, evaluations, and implementation of lessons learned. Some had regular sessions for professional updates while others had more random and seldom activities. However, all interviewees expressed a need for more collaboration exercises with other organizations involved in crisis management.

4.2.2. *Technology support for COP*

All organizations interviewed (except for one) use GIS and digital maps as a necessary tool when handling crises, in combination with organization-specific logging systems and procedure repositories. The system vendor interviewed is the provider of the map services for the first responders, but each has an agency-specific GIS system. The fire and health C3s can communicate by sending each other the position for the crisis event in their agency-specific GIS, but this function is not in place for the C3s of the other responders included in the interviews. An issue frequently mentioned during the interviews was location uncertainty, and this was also evident in the communication in the audio-logs as illustrated in the following example:

Fire services:"*We don't know where to go.*"
Police services: "*You should go to location X.*"
Fire services: "*Can you hear us*?"
Police services: "*Yes.*"
Fire services: "*What is the exact address*?"
Police services: "*We are not sure.*"

In this example, the C3 for health services was receiving the call with the exact address, but there is currently no function for communicating this location to the other C3s in a common map display. Also, in the hectic environment, they did not capture the location uncertainty of the other C3s.

When the participants from the first responders were asked about what features they would like to have included in a COP, several mentioned the opportunity to visualize and track other organizations' operative resources in common operations:

«*I wish both ambulance and fire departments were in the same GIS as us, in that way we could see their operative units, and I could see how far they have come, and I can form a visual picture of, for instance, a gathering point for injured and deaths because then I would see a lot of ambulances there.*" (Emergency Dispatcher, Police services)

Also, the results from the interviews show that the first responders need access to several other information elements than the location, which would also be valuable to be visualized; this involves both static and dynamic information. Several respondents argued that common visualization of the affected area(s) would provide important information, for instance, that someone puts a circle in the map, for important

information elements within this area to be accessible and highlighted for all. This could be private homes, cabins, flooded areas, nursing homes, closed roads, power outages, cultural heritages, etc. As stated by several responders related to visualization of common features in a GIS: *"Many have trouble with their lack of local knowledge to know where all these things are*." (Emergency Dispatcher, Fire services)

"*It would be huge progress if we all could see the same GIS live, because then if someone has new information they could insert it, for example, where is the incident commander's gathering place, where is the fire, what are considered safe zones, where are zones for rest and so on.*" (Emergency Dispatcher, Fire services)

"*We should be able to insert, for instance, let us say that it is a fire nearby a factory and that the factory produces explosives, then it could be pre-implemented symbols on these kinds of locations."* (Emergency Dispatcher, Health services)

Including information on dangerous material on a common map would also give information about the need for equipment and protective clothing.

The organizations that are not characterized as first responders also use different types of digital maps, except one organization that only used wall mounted paper maps The majority of the respondents also use additional commercial GIS solutions because their main map system does not fully cover their information needs. An example of an additional commercial map mentioned by all respondents was a map overview of the weather forecast.

Regarding tools for communication, the first responder agencies use NPSN (see section 4.1.1) as the main channel for verbal communication, while the other organizations interviewed did not have access to this. The latter organizations thus mainly use telephone and e-mail for communication.

4.2.3. COP and common situational understanding

The interviewees were asked to provide their reflections on the terms COP and common situational understanding, and how they establish this in current practice, including difficulties in terminology and information sharing processes.

A common view among the interviewees was that the term COP was related to a picture, and in their work environments, this picture is typically a map interface. Some reflected on the term "operational" and related this to various important visual information that could be used for providing a higher level of situational awareness related to the specific stages of the crisis operation. According to the majority of the interviewees, the difference between COP and common situational understanding is that COP represents a visual object (this is what they see of the situation) while common situational understanding is their common interpretation of this visual information.

Some quotes that support this are as follows:

"The COP, the picture is, ok, there is the fire, right? And it is this and that. The understanding is what can happen next. However, this is highly connected." (Emergency Dispatcher, Fire services)

"The picture could be very detailed, but it may not be perceived in the same way by all involved actors" (Emergency coordinator, Municipality)

"It is a difference between the picture and an understanding. You must understand the picture to get an understanding of the situation" (Emergency coordinator, Municipality)

"An objective picture is what we got, but how do we understand the picture? It is how we subjectively comprehend the objective [picture]*."* (Emergency Dispatcher, Police services)

"We must share our view of the situation picture, to build understanding. All involved ought to contribute to this understanding, so that it is not, for instance, only department X's understanding that it is this and that." (Emergency Dispatcher, Fire services)

All informants talked about a shared interface in a GIS as the optimal way to build a COP, where the involved agencies can communicate by inserting organization-specific visual information on the same platform. However, they also pointed to that using a single COP is not functional, as too much data gives information overload:

"Too much data in the map, that's not information, that becomes only data and noise". (System vendor)

In response to the question of how to build common situational understanding, the majority of the respondents answered that verbal communication is used for negotiating their understanding of the COP with the collaborating actors and plan for further actions. Verbal communication between different professional organizations might be subject to a misunderstanding resulting from different terminologies being used. While most of the respondents stated that they do not experience issues with terminology in general, they also pointed to examples of areas where terminology could cause possible misunderstanding. One participant commented:

"*But of course, fire services have some geographical terms (…) that other organizations don't understand, and this makes a map required for an explanation on different positions"* (Emergency Dispatcher, Fire services)

Further, abbreviations and agency-specific terms are a common issue:

"*We have acronyms that are unknown for other actors*" (Emergency Dispatcher, Health services)

"*Those Latin words are typical health department*" (Emergency Dispatcher, Police services)

The latter is also echoed by another respondent:

"*We are not familiar with the terminology.. the Latin and.. MORS* [Latin for a dead person] *for example. I misunderstood that term one time; I thought the person was unconscious, which he obviously was not.."* (Emergency Dispatcher, Police services)

The first responder agencies pointed to the NPSN and the possibility to communicate in common call groups as a major advantage for achieving common situational understanding: "*The NPSN is huge progress, for collaboration, in common call groups where we all get the same information at the same time*" (Emergency Dispatcher, Police services). However, some of the interviewees also argued that the messages in the NPSN have to be more clear, specific, and structured than today's practice to achieve a common situational understanding based on the contextual and visual information.

5. Discussion

Based on the literature review and analysis of findings, Figure 3 presents a framework connecting the activities and processes involved in establishing a COP as a basis for common situational understanding. The different elements of the framework are discussed in the following.

5.1. Develop SMM by common training

The quotes from the interviews regarding common training corroborate former research concerning the importance of knowledge on each other's responsibilities, needs, and tasks for successful collaboration. These results underpin previous studies on high-performance human teams and show the importance of the development of a shared mental representation. Common training and collaborative exercises are important for the development of SMM, and also, a common ground such as shared knowledge, language, and beliefs is a facilitator for communication (Kuziemsky & O'Sullivan, 2015). This research suggests that the first step of the framework must be to investigate information requirements in different scenarios and use this as a basis for common exercises for developing SMM.

5.2. COP structures

All crisis events are unique, thus complete access to all relevant operational information is impossible. However, the COP structures must be able to combine both the static and dynamic information that is known to be needed in different settings. Training and investigation of specific information needs from evaluation reports and/or talking to

experts provide knowledge on what to implement in the COP as static and dynamic information requirements. A basic feature that several of the respondents point out is a common visualization of different locations in the GIS. This finding is supported by the many messages in the audio-logs concerning location, and many of these being about location uncertainty. In line with these results, a previous study identified that the lack of relevant, complete, and accurate geo-information is a crucial reason for limited SA and a reason for delays in the dispatch process (Chen, Sharman, Rao, & Upadhyaya, 2007). The interview results show that information such as thematic data specific to the relevant area and/or hazard, for instance, flooded areas, nursing homes, etc. and real-time specific data such as visualization and real-time tracking of resources are wanted. Further, the interviews indicate that the COP structure should be able to capture and relay any information elements that may impact plans or decisions to be made, such as the need for special protection before entering hazardous areas. This information could be pre-implemented in the GIS system. While some of the actors would probably already have access to this kind of information, the distribution of this should not be dependent on verbal communication alone. In this kind of event, both visual and verbal information seems to be relevant. One of the important procedures for communication in the NPSN is that after new information is provided, other participants must confirm that the information is received. However, the audio-logs show that this is not followed consistently in current practice. Actually, many of the messages communicated are not confirmed at all. This might indicate that important common information can be overlooked in today's communication process.

The results discussed in this section suggest that the COP structure must involve several actions that must be made possible. Firstly, the opportunity to share a common GIS interface must be in place. This GIS interface should contain pre-implemented features which are related to information needs in different contexts, and the possibility for the actors to draw agency-specific information from the COP. Further, it should include the opportunity to insert dynamic operational information based on the actors' present SA. In this sense, the COP functions as an information warehouse for both pre-implemented static information and dynamic operational information, and the involved organizations that have access can both receive and insert important information.

5.3. COP collaboration support

As the COP structures provide the community of responders with available static and dynamic visual information, the related work processes must also be adjusted to these features. For instance, in the example from the audio-log message exchange, the C3 must implement structures for sharing such information in a common GIS, and the operative units must be able to receive and confirm the information. Another example is the possibility to insert operational information such as the location of fires, safe zones, and "flags" that indicate possible hazards. In this case, the COP concerns how the information in the structure is represented. The map interface is an important tool for emergency stakeholders to build a COP (Robinson, Pezanowski, Troedson, Bianchetti, Blanford, Stevens, Guidero, Roth, & MacEachren, 2013). However, how the COP represents information and how the users understand the information is not necessarily corresponding. The COP must use standardized symbols because the users have to share the perception of what the different symbols are presenting in the emergency context (Robinson, Roth, & MacEachren, 2010). Based on the assumption that a single COP is not possible, the information in the COP must be available, known, univocal in terms of symbols, and scalable for avoiding information overload. According to the map provider, presenting all information to all actors results in information overload.

In addition to cartographic choices for the base map, the COP structure demands more spatial data that visualize operational information such as resources and possible hazards. The symbols must contain information beyond the static, for instance, directions and speed of operational units. Also, if the users can insert emergent information on the event development and context, all actors need to understand what it means. One possibility is to integrate the ability to insert textual explanations either by the provider of the new information or integrated into the system. Having the opportunity to insert text leads to possible difficulties related to terms (Abbas, Norris, & Parry, 2018; Wright & Budin, 2001, etc.), and this is further supported by the results from the interviews. For instance, the example regarding the deceased person (MORS) shows how misunderstanding can influence the working processes as the response for a person that is confirmed dead and for an unconscious person is very different. In establishing a COP it must be acknowledged that the actors might have a different understanding of terms that are connected to the shared information, and this understanding impacts the working processes.

The COP should facilitate processes, decisions, and actions that promote collaboration. For instance, with a heavy workload and urgent tasks, it will be difficult to support each other in decision-making processes. The COP must provide the users with scripts for inter-agency collaboration and tools for an equal response regardless of which actor is the direct observer or handler of the situation. In current information sharing practices among Norwegian first responders (police, fire, and health services), the national triple-alert script (see section 2.2) is applicable across the three first responder services and geographical units. This script secures that all actors receive the same information regardless of which agency that handles the first inquiry in the nine scenarios listed in section 2.2. In general, the respondents indicate a challenge regarding what information needs to be shared, and further who needs the information. This is echoed in the evaluation of the "Viking Sky" incident (see section 4.1), where a relevant actor was not contacted in the initial phase, and it was not implemented in their routines to alert this actor in such crises (DSB, 2020). There are several evaluations of incidents in Norway that uncover problems with structures for information sharing (DSB, 2014; 2020; NOU 2012:14, 2012), where systems for decision-making are an important part of these structures. The report after the terror act on Utøya July 22nd, 2011 (NOU 2012:14, 2012) also documents how missing systems for decisions and actions might lead to fatal mistakes.

According to the results in this study, it can thus be suggested that a COP should include scripts or procedures that are generic or flexible enough to be implemented in different scenarios. The triple-alert routine represents the first and only example of such a common script supporting the Norwegian emergency response. However, this routine is limited to the acute phase of the nine scenarios and the first responder agencies. Another important finding regarding decision-making is that most of the informants from the emergency management organizations state that their past experience affects their decisions. This results in a possible challenge of biased decisions. However, if the community of responders has access to scripts based on knowledge from previous research and evaluations, similar to the triple-alert routine, such a structure will guide the actors to the important information that characterizes a scenario and suggest possible actions. For avoiding misjudgments and hasty conclusions, it is also important to consider that stress plays an important role in decision-making processes (Steigenberger, 2016), and that information overload creates simplified mental models (MM) (Van den Homberg, Monné, & Spruit, 2018) witch further can lead to poor decisions. Therefore, it is important to consider human mental processes in the development of procedures or scripts, such as the two-mind system defined by the RPD model (see section 2.3). The RPD model points to the need for the two-mind systems to be involved because actors tend to be biased by highlighting previous experience, and thus need system two for assessing pattern-matching options in a particular situation (Luokkala & Virrantaus, 2014). The triple-alert routine can be seen as an example of how a structure considers the RPD model. It is a common script that leads all the involved actors to understand the same scenario (situation), collect the critical information, and further guide the users to consider possible options.

The triple-alert routine forces the actors to activate system two for considering other options and, to some extent, learn about the other collaborating actors' understanding and information needs. If considered in the development of such procedures, the RPD model can support information sharing and decision-making tool in time critical situations, by guiding the actors to perform rational decision-making by imagining multiple options and seeing connections and contradictions in the critical cues of the situation.

Since the use of collaboration scripts has been demonstrated to support SA (Appelman & van Driel, 2005), the implementation of similar common scripts as a supportive mechanism in the COP can help the actors coordinate behavior and reach consensus in decisions and actions (Artman, 1997). Taking into consideration that operational visual information can be divided into several levels of detail in the COP, allowing for zooming-in and zooming-out effects for observation and diagnosis, scripts can support the community of responders' different needs in a COP. Thus, collaboration scripts based on the RPD model can function as a support in the information sharing and decision-making process, and also strengthen the SMM because of the shared consciousness on collaborating agencies' coordination routines and knowledge.

5.4. Common situational understanding

Common situational understanding involves aspects of knowledge management (KM) (Yates & Paquette, 2011), which is hard to integrate into software as an exhaustive solution. Knowledge sharing most often occurs through human interventions (McNeese et al., 2006). One of these interventions is described by a respondent in this study as negotiating with other members. Further, when the participants in this study were asked about how they comprehend the terms "common operational picture" and "common situational understanding," and how to build and share this, the majority commented that the COP is more or less a state of the current situation as represented by an objective "picture," while common situational understanding is the comprehension of the features in the picture and the possibility to project what can happen next. These results support the idea of the COP as a baseline assessment for building common situational understanding and reflect the argument of Wolbers and Boersma (2013) who demonstrate that different professionals interpret similar information differently. They thus argue that "a trading zone" for negotiation for developing collective sensemaking of information in a COP is necessary, because the warehouse metaphor overlooks the fact that actors may give different meaning to the same information. Also, since the organizations in our study use different structures and systems for decision-making and actions, the negotiation process with colleagues is an important feature and the trading zones provide the opportunity to efficiently exchange relevant verbal messages. Although several of the participants suggested the COP should be based on a GIS interface and should include some features for decision-making support such as additional information connected to the map-based information, many of them also mentioned the verbal communication as a highly important part of building common situational understanding. This demonstrates how not only individual sensemaking is important, but thatcollective sensemaking is also crucial for all actors to develop a shared understanding as a basis for coordinated action (Maitlis & Sonenshein, 2010).

The trading zones can function as specific instances of negotiation for acquiring and exchanging information, where the actors can verify important issues for reaching a common situational understanding. The negotiation involves combining different cues, scripts, roles, and actions that are a result of the involved actors' professional background (Weber & Glynn, 2006) and their understanding of the COP. The negotiation can be described as a process of dialogic coordination (Faraj & Xiao, 2006), which can be used as contextually and temporally situated responses to, for instance, deviations from expected outcomes of any kind. This way, according to the interviewees' statements, the actors have the opportunity to clarify misunderstandings, quickly provide important situational updates and confirm received and understood information; and thus achieve collective sensemaking.

If one considers the COP as a process that facilitates actions based on the analyses of the available information and the sharing of this (Borglund, 2017), effective coordination and communication are required both for understanding the COP and further to achieve common situational understanding. The results from the interviews indicate how the process of using a COP to gain common situational understanding is related to the three levels of SA. The information in a COP is largely associated with the detection, recognition, and identification of the elements in a specific situation, which are the components of level 1 SA. The sharing aspect, in this sense, will be a common visualization of important elements, common collaboration scripts, and verbal communication. Thus, the COP features will guide the actors through the "trading zone" into an understanding of the current state in terms of what the different information elements mean, which characterizes level 2 SA. Again, a new "trading zone" where the actors can share their interpretations concerning the direction of the situation based on level 1 and 2 SA information and professional knowledge, will lead into level 3 SA. The COP and the "trading zones" will result in collective sensemaking of the situation that leads to a common situational understanding. However, emergency environments are complex, dynamic, and unpredictable (Endsley, 1995; McEntire, 2002) and one must consider Fig. 2 as an ongoing and recurring process. The "trading zones" serve as an arena for the actors to share expertise and negotiate the value of alternatives (Wolbers & Boersma, 2013), provide important situational updates, and clear up misunderstandings. Turoff, Chumer, de Walle, and Yao (2004) argue that the free exchange of information without the side effect of information overload is necessary when several actors from different organizations must collaborate. The involved organizations are either a specialist or a generalist in the scope of different situations in the emergency environment, where the specialists have stronger expertise in their professional area, while the generalists would influence policy decisions which could affect the structure of the information sharing (Turoff et al., 2004). In this sense, it is important to pay attention to the professional culture in the message exchanges, where the structure for communication should consider both specialists, generalists, and other involved organizations. Such a communication management structure can facilitate the sharing of the more customizable and correct amount of information, which is important for avoiding information overload. Thus, a common structure for message exchange should be considered in the "trading zones" using the common call groups in the NPSN. Fig. 2 shows how a combination of verbal and visual communication together constitute the basis for sharing the required information for developing the COP and negotiate a common situational understanding.

6. Conclusion and further research

The empirical basis for this study includes several different data sources; interviews with stakeholders from various emergency management services a GIS system vendor, and managers from the NPSN, and analysis of audio-logs, public documents, and previous research studies. The dataset conveys an impression of how stakeholders from different organizations can use systems to enhance their collaboration processes and utilize each other's professional knowledge and expertise to achieve greater situational awareness in terms of common situational understanding at an inter-agency level.

The conceptual framework presented in this article has been developed to identify and discuss important features of the COP, and structures for cooperative work settings to use the COP as a baseline assessment for achieving common situational understanding in operations involving several different organizations. Firstly, it is important to develop SMM by common training and prepare for different scenarios. Secondly, the COP must provide several detailed levels of data allowing

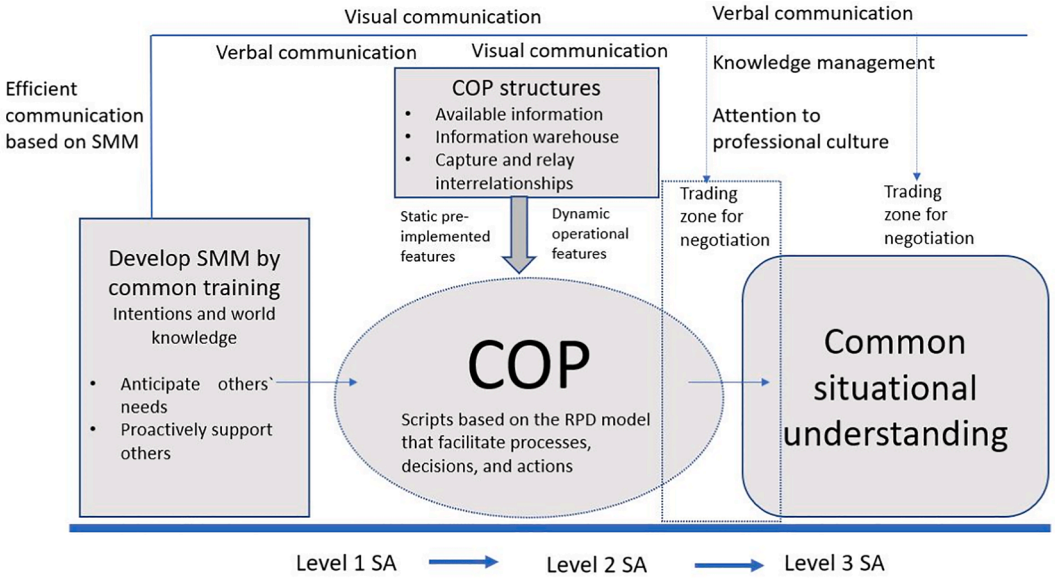

Fig. 2. A conceptual framework on how to use the COP as a baseline assessment for achieving common situational understanding.

zooming-in and zooming-out effects for observation and diagnosis. Thirdly, the COP should involve scripts considering the human mental processes for sharing information and supporting collaborative decision making. However, technology support alone cannot provide common situational understanding, thus the data provided by the COP should be seen as a supporting tool and not as a substitute for effective communication. Therefore," trading zones" for verbal negotiation based on an efficient message exchange strategy developed prior to the crisis is important for achieving common situational understanding.

The paper contributes to previous research by investigating the actors' assumptions on the concepts of COP and common situational understanding, and by this providing a clearer distinction between these concepts when it comes to practice. Further, this distinction provides an understanding of the steps in how to get from one to the other. Based on the practical view of the community of responders, the framework can also contribute to emphasize important steps when developing new procedures and tools in practice. The findings from this study imply a strong need for improvement in the area of building common situational understanding, and the framework can supply planning processes on how to make improvements based on the users' perspective.

The somewhat limited number of stakeholders interviewed from each organization could be noted as a possible limitation to this study. With only one to three respondents from each agency sharing their views and experiences, this could possibly exclude perspectives and points of view from other actors in the same organization. However, the informants were selected because of their first-hand knowledge of crisis management in practice and could thus provide relevant knowledge and insight. Also, the public documents analyzed in this paper support the informants' perspectives. Further, the analysis sometimes required a process of translating the informants' experiences related to specific scenarios to more generic insight on the process of establishing a COP and common situational understanding.

This paper builds on the stakeholders' views on the terms COP and common situational understanding, and how to achieve this in practice. There is still a need for further investigation of how enhanced possibilities for information sharing affect the community of responders' situational awareness and working processes. The different organizations use various systems and structures, which means there must be a redeployment of parts of their procedures to adapt to the enhanced access to information. A natural progression of this work is to explore the stakeholders' views on how to successfully implement such information access in their working environment, and systems for negotiation of the COP. For instance, the providers of new information must have the possibility to quickly verify that the information is received and understood by the right actors at the right time.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Using Live Video for Communication between Lay Bystanders and Emergency Dispatchers in Command and Control Centers

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Abstract: Emergency response operations are usually initiated by emergency calls from lay bystanders at the incident scene, providing information that is vital for assessing the situation. While the communication is mainly verbal, the use of live video systems for providing real-time visual information is increasingly being focused. This study presents an analysis of work practices in command and control centers (CCC) in Norway and documents experiences from early-stage adoption and use of a live video system. Based on interviews with emergency dispatchers, our study contributes knowledge on how this new source of information is incorporated in the emergency response decision process in the CCCs. The results show how the use of live video can enhance situational awareness in multi-agency operations, especially in unclear situations. However, the benefits of using video need to be balanced against the additional manual operations required, which may cause delays in time-critical situations.

Keywords: command and control centers, live video support, information collection, situational awareness, normalization process theory, decision-making, emergency management, dual-process theories

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1 Introduction

Successful crisis management depends on the ability of emergency management organizations to collect and handle timely and relevant information, determine the urgency of the crisis, make proper decisions, and perform the right actions. This relies upon the actors' achievement of situational awareness (SA) (Endsley, 1995). The emergency dispatchers at the agencies' command and control centers (CCC) (i.e., fire CCC, medical CCC, police CCC) rely on access to accurate and relevant information from the available sources to build an adequate SA for the specific situation. Several aspects must be clarified before making a decision. This often requires the dispatcher to seek additional information to be able to proceed with the operation.

Previous studies have identified significant information gaps for decision-making during emergency operations (e.g., Bharosa et al., 2009; Van den Homberg et al., 2018). As the verbal information provided by lay bystanders in emergency events can be misleading or limited, emergency dispatchers often need to make decisions based on insufficient SA (Bolle et al., 2011a). Videoconferencing can be used to enhance information collection in CCCs. With video cameras now available in nearly every citizens` pocket (integrated into their smartphones), an emergency dispatcher can utilize the video function to more efficiently build a SA than through voice or text alone (Blum et al., 2014). Further, researchers argue that the use of video may help medical dispatchers to better instruct the lay bystanders remotely to do the right actions for supporting a victim (Johnsen and Bolle, 2008). However, since using a live video system is a novel practice in the CCCs, we have a limited understanding of how live video is being incorporated into the workflows. Therefore, this study aims to answer the following research question: *How is the use of live video systems for data collection incorporated in the emergency response work process in command and control centers?*

To answer the research question, this study investigates the work practices in three different Norwegian CCCs (including medical and fire CCCs), engaged in current projects on the use of live video for communication with callers from the incident scene. The empirical basis for the study is qualitative interviews of emergency responders from the CCCs and expert users of live video conferences, supplemented with an observation of the system in use. The Normalization Process Theory (NPT) (May, 2009) is used as the main theoretical lens, to understand the dynamics of incorporating the live video system and to assess and understand the usefulness of the system. In addition, the study builds on former research on SA and decision-making. The study presents experiences from early-stage adoption and use of live video streaming from lay bystanders in CCCs and discusses how this technology can be embedded in the workflow to improve the emergency dispatchers' SA. Application of the NPT to the emergency management domain can enable a deeper understanding of the normalization process across agencies through focusing on the four dimensions of coherence, cognitive participation, collective action, and reflexive monitoring. As literature shows, the NPT has so far mainly been used in research on healthcare innovations (e.g., Mishuris et al., 2019; May, 2018). Thus, our study also contributes to expand the application of this theory to the domain of emergency management.

The next section provides a background on CCC work practices and the use of live video in CCCs. Section 3 introduces the theoretical lenses for the study, including situational awareness and decision-making, and Normalization Process Theory. This is followed by a presentation of the research approach in Section 4. The results of the data analysis are introduced in Section 5 and discussed in Section 6. Section 7 presents conclusions and implications.

2 Background

This section presents the current CCC work practices, the role of situational awareness and decision-making in emergency dispatching, and the use of live video in CCCs.

2.1 CCC work practices

Studying the work processes of emergency managers is elusive as a result of the diversity in several elements (Baumgart et al., 2008) (e.g., education, training strategy, tools, culture, and procedures for decision-making and agency-specific actions), both among the various organizations and within each organization. In a CCC, several dispatchers with different experiences will often be working on the same emergency event. While the other Nordic countries only have one emergency number (112), Norway has a dedicated emergency number to each of the different first responder agencies (i.e. fire 110, police 112, health 113) (Ministry of Justice and Public Security, 2009). Thus, in multi-agency emergency responses, one of the CCCs is initially contacted by a caller and then has to contact and provide correct information to the other CCCs. In other countries, there are different models of how to organize the use of the emergency number (112) where the Public Safety Answering Point (PSAP) either performs the interviews or forwards the calls to different dispatchers (for example the police for further interview) (EENA, 2019).

The CCCs dispatch the operative unit's fleet consisting of different resources, e.g., ground, air, and water vehicles. Further, they act according to certain protocols and the dispatchers` professional experience. Also, emergency operations require effective information sharing between stakeholders (Salas et al., 2015) and they must provide the relevant information to the right actor at the appropriate time (She et al., 2019). The emergency dispatchers serve as network hubs, and their task is to filter information and decide which information to relay (Steigenberger, 2016). In Norway, this information exchange is governed by different agency-specific protocols and a novel procedure for data collection and sharing that includes all three first responder CCCs, referred to as *the triple alert routine* (Norwegian Directorate for Health, 2019). This is a common procedure for inquiry and action covering nine pre-defined scenarios: bomb threat, fire in a building, acute pollution, tunnel accident, ongoing life-threatening violence, a person in the water, accident at sea, avalanche, and traffic accident. The procedure describes when and how a triple-alert between the first responders should be initiated and implemented.

This novel routine is a response to the need for more common strategies in the CCCs' procedures as there are several similarities in the work processes. *Firstly*, they have the same role in society (see Figure 1). All CCCs function as the public's first interface with the emergency services in an emergency event. *Secondly*, the dispatcher must secure that the important information about the incident is collected by using verbal communication via telephone and possibly search for relevant information in their information systems (IS). *Thirdly*, they must decide on whether the situation requires assistance from one or several emergency services. *Fourthly*, the workflow is guided by protocols for data collection, actions, and guidance in line with the internal systems. This means that the dispatcher must take responsibility to alert resources and response personnel, and exchange necessary information with all parties involved. Nevertheless, in all operations the main goal for the first responder agencies is saving lives, regardless of their distinct focus which is determined by agency and type of incident (National Police Directorate, 2011; Smith and Dowell, 2000). In many European countries, depending on the type of emergency, the dispatchers are reinforced by indexes and interview support (checklists) adjusted to the incident-type protocols (EENA, 2019). In Norway, the medical CCCs use the Norwegian Index for Medical Emergency Assistance (Index) (Nakos, 2018) as dispatch guidelines. The police and fire CCCs also use similar procedures, but descriptions of these are not publicly available.

The CCCs` responsibility does not include leading the operation itself or managing the resources and efforts at the scene of the incident. This is the responsibility of the incident leaders on the emergency site.

However, the CCCs support operative field management and participate in decision-making (Norri-Sederholm et al., 2017). They must follow an operation until measures are terminated, e.g., following an ambulance transport in their GIS until arriving at the hospital.

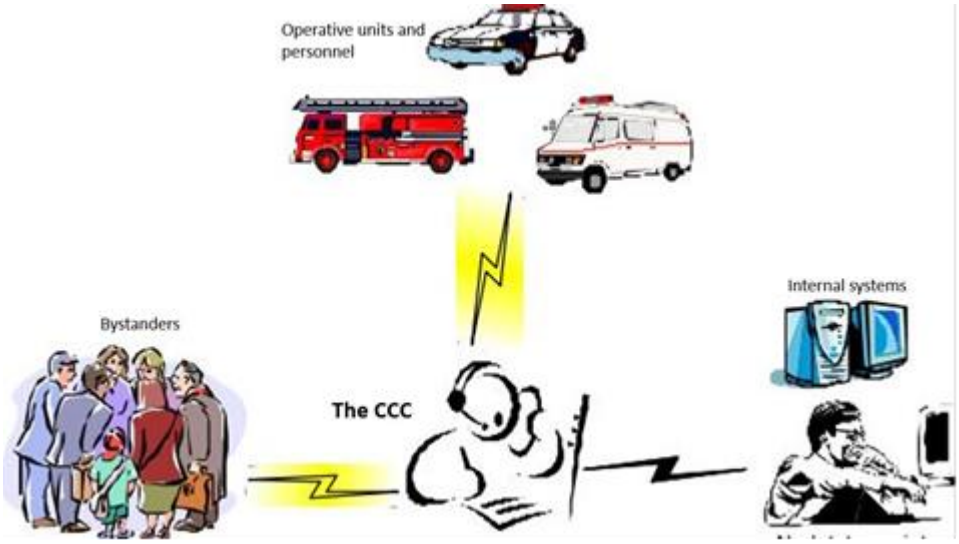

Figure 1: The role of CCCs in society. Adapted from the Ministry of Justice and Public Security (2004, p. 13).

2.2 Use of live video in CCCs

Communication with lay bystanders in crises using video is increasingly focused (Melbye et al., 2014), e.g., in the EMYNOS project (Markakis et al., 2017) involving design and implementation of a next-generation platform to facilitate rich media emergency calls with voice, text, and video. Further, the Next Generation 112 projects (EENA, 2017) conduct testing that involves several European countries. One example is Turkey, where an audio and video module was implemented in the 112 system, enabling face-to-face emergency calls. Bergstrand and Landgrens`study (2009) on live video for information sharing between emergency responders reported that live video provides new capabilities. While documentation on the impact of these projects on the CCC workflows is still limited, some studies report that video calls can introduce new issues such as information overload and privacy breaches (Neustaedter et al., 2018). For example, using video can potentially lead to unintended privacy invasion for the callers as they may get more involved by filming the incident rather than only providing verbal information (Boyle et al., 2009; Park et al., 2016). On the other hand, studies also document that use of videoconference has a positive impact on the interaction between medical emergency dispatchers and lay bystanders (Bolle et al., 2011b; Bolle et al., 2009; Yang et al., 2009) by improving the guiding process between the dispatcher and the bystander. Further, Neustaedter et al. (2018) studied the potential of using videoconference in 911 centers, and the results showed that this could provide valuable contextual information, and help to overcome dispatchers` challenges related to information uncertainty, location, and communication problems.

Emergency dispatchers must remain calm and avoid mistakes while assessing the information they receive during incidents. Approximately one-third of all emergency calls cause peritraumatic stress (Pierce and Lilly, 2012). However, there is still limited scientific understanding of the negative effects of occupational stress on dispatchers (Steinkopf et al., 2018). Literature on this topic also points out that even if the dispatchers do not directly witness the traumatic event, their work is characterized by exposure to tough details from incidents (Gurevich et al., 2007). The stress can also be increased when dispatchers imagine what the lay bystander is telling them (Naustaedter et al., 2018).

The Norwegian fire CCCs are the first in Scandinavia that have access to a common solution for receiving live video (IncidentShare^{TM}) when calls are made to the emergency services number 110. This system has been in use since spring 2019. The implementation procedure for the Incident Share system was demonstrated to the first author in a fire (110) CCC. The system enables callers from the incident scene to stream video and audio directly to the CCC. The dispatcher sends an SMS with a link to the caller, and by clicking on this the caller gives the dispatcher access to the mobile phone`s camera and microphone. Video and audio are then streamed to one of the screens in the CCC. Thus, unlike for closed-circuit television (CCTV), the video streaming requires consent from the lay bystander. It should also be noted that the lay bystander cannot see the dispatcher, hence it is not a face-to-face communication system. The video is recorded and stored locally in the CCCs for a few hours, however, the dispatchers cannot get access to the stored videos after the streaming without consent from the management. It is therefore impossible for the dispatchers to misuse the videos for personal gain.

3 Theoretical lenses

This section introduces the theoretical lenses guiding the data collection and analysis.

3.1 Situational awareness and decision-making

Effective emergency management requires the involved actors to have a continuously updated situational awareness (SA) (e.g., Dilo and Zlatanova, 2011; Endsley, 1990). SA is formally defined as "the perception of elements in the environment within a volume of time and space, comprehension of their meaning and projection of their status in the near future" (Endsley, 1995, p. 36). This definition refers to three hierarchical phases, described as level 1 SA (Perceiving critical factors in the environment), level 2 SA (Understanding what the critical factors mean), and level 3 SA (Understanding what may happen within the situation in the near future). In Norway, the dispatchers build their SA by collecting information using different technologies such as the Norwegian Public Safety Network (radio network), different internal information systems, and Geographical Information Systems (GIS) (Stiso et al., 2013).

An emergency dispatcher`s need for information that supports SA is naturally narrowed down to elements that are important to reach their professional goals. Attention to the elements that are important for the specific situation is crucial for effective decision-making and response (Endsley, 1999). Because of the limitations in human information processing capabilities (Endsley, 1999; Lamb, 1991), the attention of humans tends to be selective. This increases the risk of using energy on some parts of the available information at the expense of possibly overlooking other more important information. Through training and experience, emergency dispatchers can quickly identify suitable patterns in specific situations from only partial information (Kinsey et al., 2019). In these cases, the actors react to their professional experiences, also known as a Recognition-Primed Decision (Klein et al., 1993). However, this intuitive judgment may have lower accuracy and is prone to systematic biases (Kahneman and Klein, 2009). This is related to the dual-process theory (e.g., Sun, 2001), that recognize *system 1* and *system 2* in human information processing. The automatic system (*system 1*) is initially used in the decision-making process, and the reflective system (*system 2*) enables humans to address events in a more calculated manner and requires more information to complete the decision-making. However, when the dispatcher receives too much information, this can exceed human cognitive capabilities and result in information overload. To deal with this, there are decision support systems for information sampling, decision-making, and response execution, such as the triple alert routine. There are positive effects of such systems (Yoon et al., 2008). Different decision support systems are applied by emergency responders worldwide and have become popular in telephone-based services in healthcare, such as for the dispatch of ambulances. These systems combine expert knowledge with algorithm-based rules that facilitate decisions and measures (Pope et al., 2013). Decision support systems are also used in the police and fire services. For example, in the US the

Emergency Police Dispatchers (EPDs) are using the Police Priority Dispatch System (PPDS) (Broadbent et al., 2018) and Emergency Fire Dispatchers are using the standardized Emergency Fire Dispatch (EFD) protocol-based system (Purvis et al., 2020).

3.2 Normalization Process Theory (NPT)

To extract the benefits of new information sources such as live video streaming into the CCCs, it is important to investigate how technology intervenes with existing workflows. The Normalization Process Theory (NPT) (May, 2006; 2009) is chosen as the theoretical lens for the empirical data collection and analysis to determine whether there are any workflow issues when implementing novel systems for information collection in complex work environments such as the CCCs. Further, in this context the NPT helps to identify the usefulness of the system and whether it justifies the effort of using it. The NPT deals with "*how and why things become, or don't become, routine and normal components of everyday work*" (May and Finch, 2009, p. 535). It emphasizes the need for a theory-driven approach to new practices that require complex changes in clinical routines (Grol et al., 2007) because a theory can provide universal and transferable explanations.

Since the use of the video system is not embedded in any procedures or integrated with the operative systems in the Norwegian CCCs, the focus in this paper is on how the dispatchers cope with the new system. The core focus of NPT is the work that individuals and teams do to facilitate an intervention to become part of their everyday routine, and thus be normalized. However, the normalization of systems implemented in different domains can also be denormalized (Murray et al., 2010) because they simply do not fit into the organization's workflows. The NPT defines four domains for investigating the intervention in the workflows, which in this context refer to the following processes undertaken by the dispatchers in the CCCs (adapted from McEvoy et al., 2014): (1) *Coherence*: the required sense-making process to favor or hinder the routine embedding of the use of live video streaming; (2) *Cognitive Participation:* the process to engage in the new practice of using live video; (3) *Collective Action*: the work the dispatchers have to do to enact the new practice; (4) *Reflexive Monitoring***:** the work to assess and understand the video streaming system`s effect and usefulness.

4 Research approach

To answer the research question, we conducted a qualitative research study using an interpretive approach (Walsham, 1995). This facilitates an in-depth understanding of using live video in a real-life context and hence contributes to the body of knowledge by investigating the technology in a natural setting (Mueller and Urbach, 2017).

The data collection included interviews, observation, and review of publicly available documents. A semi-structured interview guide was developed, including open questions categorized based on the four domains of NPT and an additional Context category (May et al., 2016) for mapping the workflows in the CCCs. The population in this study was Norwegian emergency dispatchers (from fire and health CCCs) with a special role as experts on the use of live video in their workplace. Since the use of live video in CCCs is novel in Norway, the number of relevant CCCs to contact was limited. The managers in three CCCs using live video were contacted for getting access to expert users that could participate in the interviews, thus a purposive sampling technique was used (Etikan, 2016). Interviews with expert users in two fire CCCs and one medical CCC were conducted (see Table 1 for a selection of themes/questions). An expert user typically has received more training in the system and is given responsibility for supporting colleagues in their use of the system. Given the limited availability of public documents that describe the routines in the CCCs (ref. Section 2), an additional interview was conducted with a dispatcher from a medical CCC that is not yet using live video streaming. This interview contributed to the data collection on the daily

workflows in the medical CCCs. The interviews lasted 40-50 minutes and were conducted either physically or using a digital platform (e.g., telephone, Skype, Teams) due to the Covid-19 pandemic. The interviews were recorded and transcribed in full.

Table 1: Examples of themes/questions from the interview guide.

Question category	Examples of themes/questions
Context	Please describe your organization (aim, tasks, protocols, routines, etc.), and your role and tasks. How do you handle an emergency incident? How do you use your procedures (algorithmic, indicative, etc.)?
Coherence (i.e., meaning and sense-making by participants)	What (if anything) do you think the live video system provides regarding data collection and situational awareness? Other issues? How does the use of live video fit with your existing data collection routines? What advantages and disadvantages does the system provide?
Cognitive participation (i.e., commitment and engagement by participants)	What did you think about introducing live video as a data collection tool in your workplace? Was there any resistance when introducing it? What direction might be desirable for the future use of the system?
Collective Action (i.e., the work participants do to make the system function)	How does this system affect your work routines? Does the system give you the flexibility to do actions on your own? Does the system provide a better basis for making decisions? Please give an example from practice.
Reflexive Monitoring (i.e., participants reflect on or appraise the system)	What do you think about the effects this system has on your organization? And the collaboration with other organizations?

The observation took place in one of the fire CCCs where the system was demonstrated and discussed in the CCC workspace. Two emergency dispatchers here showed how they use the system and answered questions. In addition, an audio log from a medical CCC was collected as an example of the use of dispatch guidelines in the initial phase of a response operation.

A review of publicly available documents was also conducted with a focus on understanding the basic workflows in the CCCs. Also, an evaluation report from a pilot project on the use of a live video system in four medical CCCs (Kramer-Johansen et al., 2020) was reviewed.

The data analysis required the authors to make sense of the collected data (Creswell, 2009) and was done in two iterations. The interviews were translated from Norwegian into English, and further coded in NVivo (QSR International). First, the coding process used the interview guide as a foundation for defining themes within the different NPT domains (Table 2). The interview statements were manually coded into the four NPT domains, the Context category, and features related to situational awareness. All themes were related to the use of live video in the actual NPT domain, based on the informants` reflections and examples from practice.

Table 2: NPT domains used for the initial analysis process.

Domain	**Themes**
Context	Workflows, procedures/structures, description of various systems, the use and interoperability, and additional systems
Coherence	Impact on SA, barriers, thoughts on use and functionality, sensemaking of the system, advantages, trust, organizational goals
Cognitive participation	Collective thoughts on implementation, use, how the system was introduced, resistance, future development
Collective action	Influence on workflows and caller interaction, required knowledge, flexibility, collaboration, additional information, decision making, actions, trust
Reflexive monitoring	System`s effect on current and previous practices, procedures

Second, an inductive method was used to code the data included in each theme into different stakeholders` perspectives and similarities and dissimilarities within each theme. Selected quotes from the interviews that underpin the results are presented in the Results section.

5 Results

This section presents the results of the data analysis. First, we present an overview of the day-to-day workflows in the four Norwegian CCCs studied. Then, we summarize the stakeholders` experience using live video systems for data collection and interaction with callers from the public. Finally, we present how the use of such live video streaming for data collection in the CCCs affects the dispatchers` SA. Section 5.4 presents a summary of the results.

5.1 Context

From the analysis, the following four aspects of the workflows seem to be common for all CCCs interviewed: agency-specific procedures and tools, triple alert routine, and documentation. This shows that the work tasks are relatively similar which can be a result of the triple alert routine. Of course, the CCCs still have different tasks and goals in various situations (Steen-Tveit, 2020), and most emergencies they handle are agency-specific. However, the results of this study show that the workflows are quite similar across all CCCs. For instance, they all start with the same initial collection of critical cues by talking to lay bystanders using verbal communication on the telephone. A “starting card” is an example of the medical CCC`s formalized initial critical cue collection (referred to as Index). The excerpt below is an example of an initial critical cue data collection between an emergency dispatcher (ED) and a caller, taken from the example audio log:

ED: *Medical emergency phone*
Caller: There *has been a traffic accident..a car is outside the road!*
ED: *We are going to help you. Where are you?*
Caller: *It is in Lillesand municipality on highway 34.*
ED: *It is in Lillesand municipality, is it by Glamsland?*
Caller: *Yes*
ED: *We will send help*
Caller: *That’s good, I think it's urgent.*
ED: *What is the phone number you are calling from?*
Caller: *Ehhh…it is xxxxxxxx*

ED: *How many cars are involved?*
Caller: *There is only one car*.
ED: *How many people are in the car?*
Caller: *Eh, there is someone hanging upside down*.
ED: *Someone is hanging upside down.. are there more people in the car*?
Caller*: Ehhh*..
ED: *Are there any others in the car?*
Caller*: No, and he is not awake*.

Notice, the dispatcher asks about the number of people in the car repeatedly until she gets an answer to the question. As one of the respondents puts it:

"*We answer the emergency call and map the situation by using the starting card; where the patient is, their telephone number and if the patient is awake and breathing normally.*" (Medical dispatcher)

The fire CCCs do not have any written initial critical cue collection tool such as the starting card in Index. However, they mentioned that all action cards (i.e. manual decision support) in the national triple alert routine start with "starting questions" and are directly followed up by "common clarifications".

"After we implemented the national triple alert routine, I feel that things are more systematized." (Fire dispatcher)

Concerning the agency-specific procedures, the two fire CCCs solely used the triple alert routine.

"*Now we have implemented common action cards* [e.g., based on the triple alert routine] *with the medical and police CCC, which I believe is more similar to the medical CCC Index. This is actually a book that you turn to for the actual incident type, and then you will be guided through what kind of questions you must ask.*" (Fire dispatcher)

The other respondents explained that incidents that are not included in the triple alert routine are mostly handled based on the dispatchers` experiences.

All CCCs document the important information in writing and register the measures taken in their incident management systems which also serve as a written communication to the operative units.

5.2 Using live video in everyday work settings

The questions informed by the NPT aimed to understand the dynamic processes that lead to the embedding of the live video system into the CCC workflows. This section is organized according to the NPT framework and the Context category.

Coherence involves the sense-making process the dispatchers have to go through to favor or hinder the routine embedding of the use of video streaming. Firstly, the dispatchers need to be aware of how they understand the actual difference between the data collection by verbal communication only, versus using both verbal and visual communication. This includes the knowledge and practice on when to set up the video and when not to. The time it takes to set up the video must not delay the proper reaction to the situation. As stated by one dispatcher:

«You cannot use video for confirming whether a patient is breathing properly or not. Any uncertainty on this would require a red (acute) response.» (Medical dispatcher)

When the respondents were asked if they knew when to use the live video and not, they emphasized that the system must not slow down the response. As there is yet no established procedure for when to use the system, the dispatchers must decide on this in each situation. When discussing the idea of implementing the system, the fire respondents were somewhat reluctant:

"It is a new system, new and different and it requires to do more actions than you really need to do." (Fire dispatcher)

Likewise, the medical respondent expressed mixed experiences. The issues raised included tough visual impressions from the incident site for the dispatchers, that it was time demanding, and that it requires extra operations in their workflow both technically and for getting informed consent from callers. But overall, the medical respondent regarded the system as a forward-looking feature for their operative work, providing value in several cases. The participants considered the video streaming system to be a natural extension of their work practices. The medical dispatcher points to that most people today are familiar with the use of the camera on their mobile phones, resulting in a low threshold for responding to live video calls.

These results are also supported in the evaluation report specific to the medical domain. For example, the evaluation showed that the total time for the response can be increased when using live video, that live video can be an advantage during the guidance of bystanders, and that the visual impressions could result in increased mental strain for the dispatchers.

Cognitive Participation refers to the dispatchers' relational process of building a new practice of using live video. This means that it is not only about individual commitment but also about building communal engagement. The respondents here expressed that age and number of years in the profession also should be taken into account as factors influencing communal engagement:

«*I have an impression that it is us, the young people, who think this system is exciting to use.»* (Fire dispatcher)

The enrolment of the actors that are required to make the system work is somewhat diverse between the CCCs. While use is more widespread in the fire CCCs, the usage in the medical CCC is more heterogenous:

«I think the system is a good idea, and that it is necessary. But I am surprised that not more of my colleagues have chosen to use it. Looking at the numbers this week, it was used in only 34 calls out of the several hundred calls we get in one week and sometimes even in one day». (Medical dispatcher)

Collective Action relates to the dispatchers' operational work to establish the new practice. The interactional workability of the system, i.e. the collaborative work that the actors do to operationalize the system so it can be embedded into everyday settings, is a key feature that both the fire and medical CCCs underpin. The respondents describe an increased focus on the system recently, with management encouraging the dispatchers to provide more feedback on how the system can contribute positively to their assessment in different situations. For example, the dispatchers need to have confidence in what the images from the live video represent and thus have to build an understanding and a culture in the CCCs to trust the information they get from the video:

"We have a professional view on the situation, and the callers are ordinary lay bystanders. They can observe a car fire…., they over exaggerate. And then we can see that it is only steam from the radiator. …. People have a great fear of fire – "it has to be extinguished!" People often put themselves in danger to do this. So we gain a lot of understanding by being able to see the incident site." (Fire dispatcher)

As ilustrated by this quote, the fire dispatcher must be able to trust what s/he sees and promote that one can trust that the image actually represents the real situation. The question above is whether the smoke really is steam from a radiator and not from something else, and whether it is safe to trust and provide advice based on that information. If not, using video would only increase the workload because it will not provide valuable information, just images in addition to the verbal information. On contextual integration, i.e., how the system works with their protocols and workload, the following response was given:

«In general, our alarm central is in need of more resources. For example, one weekend was extreme with me having to respond to 150 calls in one hour and 21 of these requiring red (acute) response. We are only two people serving all calls, and with 21 red responses in one hour (in addition to all the other calls) you do not have time to connect the video system. And it does not work to be «stuck» in a video so that you have to park incoming emergency calls.» (Medical dispatcher)

The respondents explained that the video system is not yet an integrated artifact into their operative information management system. This provides more work operations and might cause delays.

Reflexive Monitoring refers to the understanding of how a new set of practices affect their work. The informants explained how they gave attention to the need for adjustments for the system to fit into their workflow. For example, in the medical CCC they had provided the dispatchers with a written reading list for the instructions they had to provide to the callers when connecting the video. Also, they were in the process of making a procedure that gives additional references for their use of the system.

"The reading list is in our intranet and you can click to see this for support if you need it (…) we have seven screens so it is possible to have quite a lot of procedures visible." (Medical dispatcher)

The fire CCCs had a more implicit structure for use, where the live video would only be used when the information from the verbal communication was not sufficient. Further, there was a continuous reflection on when to use the system, rather than whether it should be used.

Another issue raised was how receiving live video from the incident scene sometimes could cause emotional stress for the dispatchers:

«Some report that they [*through use of video*] *have got visual impressions that they have not been prepared for, and that they really would have preferred to be without.»* (Medical dispatcher)

5.3 Features related to SA

Emergency dispatchers` SA is highly dependent on the information provided by the lay bystanders (Linderoth et al., 2015). The respondents talked about how the video system supports their SA in several ways: (1) the dispatchers can use the system to assess if this is a situation to respond to at all; (2) they use the system to evaluate the degree of different situational elements (e.g., the severity of bleeding, the color of smoke); and (3) they use the system to get an overview of the context and adapt measures and advice according to what they see. The following answer illustrates the above-mentioned points:

"I think it affects our situational awareness a lot because we have probably sent a lot more resources than we might have needed at some incidents before, where it turned out that "wow, why did we send in this situation, it was nothing". So it helps us in terms of resource use and whether it is an event at all." (Fire dispatcher)

5.4 Summary of the results

Table 3 provides a summary of the results divided into context, the four NPT domains, and situational awareness.

Table 3: Summary of the results.

Category	Results
Context	• Four aspects of the workflows are common: agency-specific procedures and tools, triple alert routine, and documentation. • Medical CCC has written initial critical cue collection in addition to the triple alert routine, as opposed to the Fire CCC which in cases not included in the triple alert routine uses the dispatchers` experience.
Coherence	• The time it takes to set up the video must not delay the prompt reaction to the incident. • There are no established procedures for when to use the system. • The system requires more actions for initiating use. • The video streaming system is considered to be a natural extension of the existing work practices. • The system can provide mental strains related to visual impressions.
Cognitive Participation	• It is considered positive that live video has been implemented as an option in the CCCs. • There is still a limited number of dispatchers that use the live video. • The youngest/less experienced dispatchers in the Fire and Medical CCCs seem to be using the live video most.
Collective action	• The collaborative work that the dispatchers do to operationalize the system is a key feature that both the Fire and Medical CCCs underpin as important. • There is an increased focus on the system, with the management encouraging the dispatchers to provide more feedback on how the system can contribute positively to their assessment in different situations. • It is considered important to have confidence in what the images from the live video represent and to build an understanding and a culture in the CCCs to trust the information from the video. • The video system is not yet an integrated artifact into their operative information management systems. This provides more work operations and might cause delays.
Reflexive monitoring	• Attention is given to the need for adjustments of the system to fit into the workflows. • A procedure is currently being developed for providing the Medical CCC dispatcher with more guidance for use.
Assessing emergencies/ SA	• The video system supports the dispatchers` SA through the ability to assess if the situation requires a response at all, evaluate the degree of different situational elements (e.g., the severity of bleeding, the color of smoke), and get an overview of the context and adapt measures and advice according to the visual information.

6 Discussion

The discussion section will consider the results related to workflow, the four domains of NPT (coherence, cognitive participation, collective action, and reflexive monitoring), and SA features.

6.1 Decision support systems in CCCs

The results show many similarities in the three CCCs' workflows despite their different domains of emergency management. The workflows in common operations are more similar than during agency-specific operations because of the use of the decision support system triple-alert routine. This type of decision support system that guides the dispatchers` data collection can help to avoid information overload and assist the cognitive dual processes by guiding the dispatcher into using the reflective system in cases where the composition of the initial information is not entirely obvious. The workflow is closely connected to the three levels of SA, where the dispatchers first collect cues for level 1, then assess these based on agency-specific protocols and experience to gain an understanding of level 2 and level 3 SA (Figure 2). Based on the interviews, some situations demand that the dispatchers must continue to collect additional data by for example asking more questions, searching in different information systems, calling other experts, or connecting to the video system (ref. Figure 2). Consistent with the literature on the dual-process theory (Sun, 2001), this means that the dispatchers need additional information and have to activate the cognitive reflective system (system 2) to address the situation. Based on the respondents' answers, the live video system appears to be a good tool for collecting additional data for enhancing SA. Ideally, the initial response and video streaming could be activated in parallel in some scenarios such as during dispatcher-assisted cardiopulmonary resuscitation (T-CPR) (Johnsen and Bolle, 2008). However, the results from this study show that because of limited resources in the CCCs and the additional workload required for setting up the live video connection, the system is used only when it is considered necessary for deciding on *how to* respond. Figure 2 illustrates how the live video system is used in today`s practice. The probability for parallel response and live video connection is likely to increase in the future when the live video is fully integrated into the existing information systems and procedures.

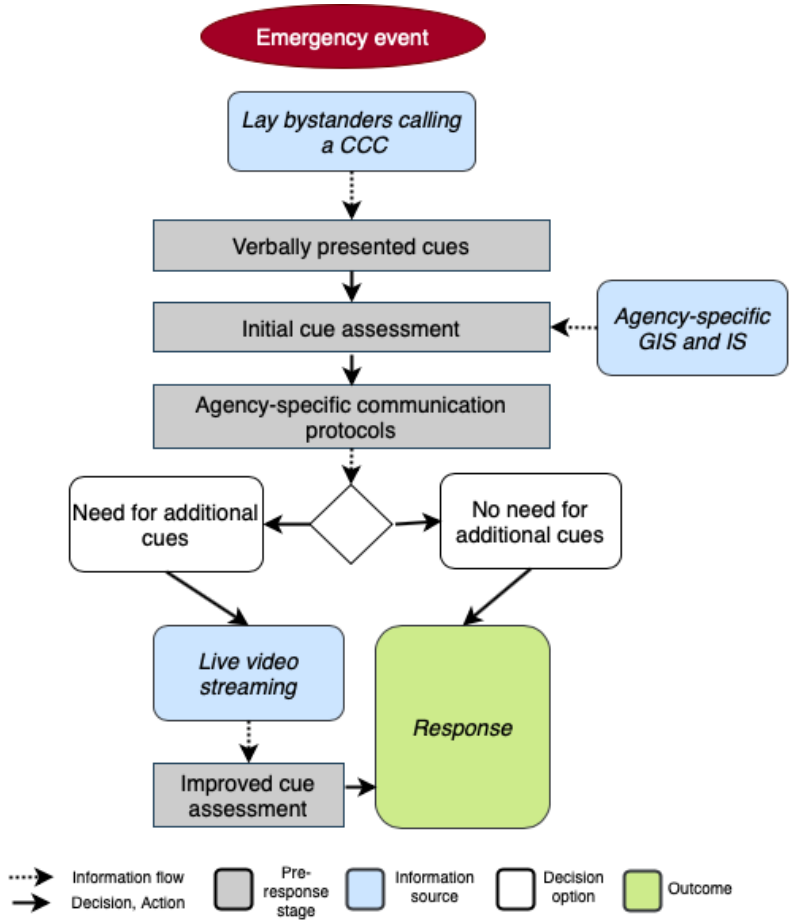

Figure 2: Incorporation of live video in the decision-making process in CCCs

Using live video for communicating with lay bystanders represents a novel way of collecting data for enhancing Norwegian dispatchers` ability to gain SA in emergency events. Since the workflows in the CCCs are relatively strict and dependent on different events and procedures, a new source for information collection must fit into these delicate work patterns. First of all, the dispatchers have a choice whether or not they should set up a video in various situations. In the *coherence* domain of the NPT, our informants argued that the video system is overall a good idea to implement, however, the time it takes to set up the video must not delay the proper reaction to the situation. This relates to the initial critical cue collection that activates the cognitive automatic system, enabling immediate response based on experience. Consider here the example mentioned by the medical dispatcher: if the patient does not breathe properly, you cannot waste any time on figuring it out. If the dispatchers assess the situation as obviously time-critical and life-threatening, the only right thing to do is to follow the agency-specific protocols and perform the defined actions with absolutely no delays. However, many situations are difficult to assess due to various issues. For instance, as highlighted by several informants, the interpretation of the severity of the situation can be quite different between dispatchers and lay bystanders. As mentioned in Section 2, video support can be a valuable tool to minimize such challenges by providing contextual information and ease communication problems (Neustaedter et al., 2018). This may especially be relevant in incidents where all three CCCs must be involved, such as the scenarios in the triple alert routine. In these scenarios, the data collection must cover all CCCs` information needs to assess the situation for making proper actions. This represents a challenge given the heterogeneous information needs among the organizations involved (Bharosa, Lee, & Janssen, 2010) A study by Singhal and Neustaedter (2018) noted that video calls provide a positive effect reported from lay bystanders because they can show rather than tell dispatchers about a situation. This can lead to a quicker way for all the involved CCCs to gain SA instead of covering all information needs solely by a verbal interview of the lay bystander. For example, using video in the avalanche scenario in the triple alert routine seems advantageous, since this scenario requires quick access to complex information (e.g., visibility, degree of danger, implemented measures) (Norwegian Rescue Services, 2018) that may be difficult for a lay bystander to convey effectively. However, one must consider that the interpretation of the images does not necessarily represent reality as the nuances and context will not always be correctly captured or represented. The technology may not be able to capture the nuances in poor light or weather conditions, such as in an avalanche scenario.

Deciding when the system should be used is affected by the various practices among different dispatchers. This can be considered as part of the *cognitive participation* domain. The respondents answer that some dispatchers do not use the system at all, partly related to their length of experience and age. For instance, one of the respondents told that some of the well-experienced dispatchers thought that they knew well how to assess emergency calls and thus had no need for video support. Another reason is that the video system requires additional operations in the digital workspace. Further, it is not included as a mandatory tool in any of the protocols but rather as an optional alternative in all cases. Johnsen and Bolle (2008) found that it is necessary to adapt the protocols to include the use of the video system, and it could thus be beneficial to insert a "consider the video in specified cases" measure. This leads to the *collective action* domain where some of the beneficial consequences of using the system were described. In many cases, the lay bystanders have no prerequisites for assessing the situation, and the dispatcher's task is to guide them and provide proper advice. An example from the interviews is that the dispatcher saw a person putting himself in danger by climbing into a burning truck to try to extinguish a fire. This illustrates a situation where the dispatcher`s advice can rescue lives by receiving visual information. Nevertheless, the dispatchers must be able to trust the information they receive. As in the example where the dispatcher characterizes the smoke as steam from a radiator, it is important to consider if this assessment is correct. Relating this to the *reflexive monitoring* domain, all of the CCCs had ongoing discussions on how to take the benefit of the system in the best ways possible by embedding the system into their practice and workflows.

Previous research shows that the users of mobile video devices (e.g., smartphones) do not necessarily consider privacy issues (Procyk et al., 2014). Using live video during emergencies raises important privacy

concerns (Boyle et al., 2009; de Vasconcelos et al., 2009). In public settings, bystanders may not be comfortable with being filmed. For example, their location and activity are elements reported to be an issue, however, with stronger concerns stated for video recording than streaming (Singhal et al., 2016). A solution that might be relevant is automatically masking out lay bystanders.

6.2 The effect of visual input

The respondents repeatedly mentioned how the video system affects their SA. For example, the visual input affects how they manage resources in different scenarios, which could save both economic and human resources by avoiding unnecessary response actions and making these more available for critical incidents. Today, the dispatchers mostly respond based on verbal information solely, thus, the visual information can better convey the complexity of the situation as the description given by bystanders might be lacking or misleading (Bolle et al., 2011). Further, the answers suggest that it might be easier to see the situation as a whole during complicated conditions, such as in complex multi-agency scenarios involving communication problems with bystanders or information ambiguity (Neustaedter et al., 2018). The possibility for sharing the same video stream between the CCCs, for example as a part of the triple alert routine, is considered an opportunity for facilitating a common SA. Because of the agency-specific information needs, one can assume that the possibility to assess visual information is beneficial for an initial operation. In this way, the agencies can simultaneously obtain the information that is important for them. However, the video system`s increased effect on the SA also has a side-effect; by only using verbal communication, the dispatchers are protected against distractions from the visual impressions, and the mental strain that these visual impressions may provide in many emergencies. Some dispatchers had reported that the use of video had given visual impressions that they have not been prepared for, and that they really would have preferred to be without. In the worst case, the visual impressions can amplify the stress caused by the tough details provided by lay bystanders as the dispatchers now actually are direct witnesses of the traumatic events. On the other hand, the dispatchers will no longer only imagine what the lay bystander is telling them and instead have a real-life image.

Based on the findings from this study, there are two situations where it seems appropriate to consider connecting the video system. Firstly, the respondents expressed that the live video system would be beneficial for incidents that are *not obvious* in the initial data collection stage and that requires increased SA for the dispatchers. This relates to the findings presented in Section 5.3 stating that live video can be used to evaluate the degree of different situational elements and to get an overview of the context and adapt measures and advice according to what the dispatchers see. Examples of such situations can be in the case of language problems, in situations where the dispatcher is unsure whether assistance is required, and/or whether the dispatcher should reroute the caller to other agencies. In such conditions, it would further be beneficial to define some specific scenarios where the video system is incorporated in the procedures, for example, in the section for unresolved issues (Nakos, 2018, Nr. 07), smaller bleedings/cuts, and smoke development. Secondly, visual contact with the emergency site seems beneficial during extreme events included in the triple alert routine, when the information is ambiguous and misleading or the bystander is unable to describe the situation. Examples of such events include avalanches, forest fires, and flooding. The nine scenarios included in this procedure are dependent on collaboration and shared SA between the CCCs. All scenarios in the triple alert routine generate heterogeneous information needs among the organizations involved, and by having visual contact with the emergency site the different dispatchers can see the important elements instead of relying solely on verbal information and thus save valuable time. However, for use of the system to be optimal, an important factor is the further integration with the existing systems. The video system must not constitute an additional operation in the dispatchers` workspace as is currently the case.

An important consideration for this topic is that a high load of incoming information can have the same effect as noise (distraction, stress, and error) when making a judgment (Klapp, 1986). An important mark

here is to identify the tipping point for when the video support is beneficial, and when it causes information overload. A multitude of information sources and formats have been proven to generate information overload (Van de Walle et al., 2013), which again results in difficulties for the dispatcher to meet the information needs of the specific situation (Gralla et al., 2015).

7 Conclusion

Since effective emergency management requires the dispatchers to have a continuously updated SA, the emergency management domain should be receptive to technological advancements. The presented study was designed to investigate the multi-agency perspectives on adopting a live video system as a data collection tool in CCCs, using NPT as the theoretical lens. This approach expands our understanding of how to facilitate a technology intervention into the organizational everyday routine, to become normalized in complex workflows such as in the CCCs. Application of the NPT to the emergency management domain can enable a deeper understanding of the normalization process across agencies by focusing on the four dimensions of coherence, cognitive participation, collective action, and reflexive monitoring. However, the original NPT does not include "context" as a core construct which is an essential component when investigating different organizations. In this paper, we have presented an analysis of empirical data based on the four NPT dimensions and added "context" as a fifth construct. The results provided an understanding beyond the impact and effect of using live video in CCCs, namely the process of integrating such novel data collection tools into the complex workflow of the CCCs.

The study has shown that as long as the novel system is not fully integrated into the existing information systems and procedures, it is regarded only as an additional feature that can be used if the situation is not clear and the time allows it. However, the results also document that the system has a place in the CCCs provided it is well incorporated into the routines. We used the NPT for mapping important elements that promote or inhibit the use of live video. The results show that the time pressure and complexity of the dispatchers` tasks affect when the video system is used. Hence, the sense-making process regarding the shared understanding of the expected benefits (i.e. the NPT coherence construct) is not optimal, which leads to low cognitive participation and low collective action. On the other hand, our informants described video streaming to be useful for diffuse inquiries; then the coherence was high and likewise the cognitive participation and cognitive action.

Limitations to this study include the limited number of informants, and the focus on early stage of video system adoption and use. The NPT was used as an analytical framework for investigating how the dispatchers cope with the system in their everyday workflow, within a limited number of CCCs involved, however, they are considered to be representative for Norwegian CCCs. Despite these limitations, the study contributes new insight on an important issue in emergency management, namely how live video can be used by dispatchers for collecting data from the incident scene, and how this can be integrated into the existing workflows in a CCC.

A natural progression of this work will be to investigate further the information overload perspective and how a new source of information, such as the live video system, affects the dispatchers in the CCCs. A focus here could be on identifying the tipping points where the information becomes unmanageable and excessive, rather than supporting situational awareness and decision making. The results also suggest a need for comprehensive mapping of different scenarios where the live video conference should or should not be used. This should then be incorporated as a part of the CCCs` procedures.

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Using a Public Safety Radio Network for Information Negotiation between the Three-Tiered Command and Control Structure

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Abstract

Multi-organizational emergency operations require effective information sharing. Existing information management tools supporting a common operational picture mainly convey factual information. However, a growing body of literature recognizes the importance of sharing interpretations and implications among the involved stakeholders for building a common situational understanding. This study aims to identify information that must be negotiated across the strategic, tactical, and operational command and control structures (C2S) for developing common situational understanding. Based on 33 interviews and a survey of emergency management stakeholders, information elements on the semantic and pragmatic levels are identified. Further, the results suggest how to use a secure radio network for facilitating information sharing so that the involved organizations can monitor and negotiate important information. These insights provide important lessons for improving information sharing in the emergency management domain.

1. Introduction

The importance of a common situational understanding for successful multi-organizational emergency management is well acknowledged in both research and practice [1], and the involved organizations require technical and organizational interoperability with common structures and processes for successful interaction [2]. In reality, the involved organizations have different communication structures, heterogeneous information needs, [3,4,5], different mandates and objectives [6], and many technologies with no interoperability [7]. These combined factors make the process of sharing information very demanding for the involved stakeholders. Radio networks are a commonly used technology for interactive verbal communication between different stakeholders in crisis operations. However, there is a need for more knowledge on how this can be exploited in the best possible way.

The common operational picture (COP) is a collective term for many suggested technical solutions for data collection and distribution [8]. For example, using text in logging systems or e-mail with or without various attachments are elements in COPs. Actors collect information that fits their professional standpoint and therefore develop different perspectives of the situation. Following this, the sensemaking process is an important component when focusing on information sharing to achieve common situational understanding [4].

Most of the information presented in the COP is factual and not sufficient for decision-makers to build a common situational understanding in complex emergency operations [9]. In fact, there is a need for information sharing at the syntactic level of *factual information*, the semantic level of *interpretations*, and the pragmatic level of *implications* to interpret the facts [10]. However, thus far, little attention has been paid to the role of the more implicit and complex concerns at the semantic and pragmatic level in the information sharing doctrine related to multi-organizational emergency management [9]. Therefore, this study examines the following research question: *What information elements must be exchanged at the semantic and pragmatic levels between the involved organizations in large complex events, and how can this be facilitated by using a radio network?*

To answer this question, literature on multi-organizational emergency management, multiteam technologies for supporting COP, and common situational understanding were reviewed. The empirical basis for this study was comprised of interviews with 33 emergency stakeholders from different emergency management organizations in Norway. A survey conducted after a multi-organizational exercise was also included. The data collection focused on large forest fires and extreme weather events, as these scenarios are expected to increase in frequency and scope due to climate

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changes and requiring multi-organizational emergency management at several levels.

The analysis suggests that while factual information can benefit from being displayed in a COP, there are specific information elements at the semantic and pragmatic levels, such as information related to the security and severity of the incident, that must be verbally negotiated for developing common situational understanding. This insight provides important lessons on how to connect the three-tiered C2S with up-to-date semantic and pragmatic information by the pre-definition of information elements, information managers, and communication paths, using a secure radio network.

Further, the results contribute to the expanding field of the information sharing doctrine [9] by identifying the more implicit, and complex concerns at the semantic and pragmatic level related to multi-organizational emergency management.

The study offers general lessons on the universal principles of the strategic, tactical and, operational command and control structure in emergency management. Furthermore, focusing on multi-organizational collaborative communication using a secure radio network during emergency management can provide valuable support during the COVID-19 pandemic.

2. Multi-organizational emergency management

In large, complex events, emergency response requires the involvement of several governmental, non-governmental, and volunteer organizations [12]. This is a cooperative process where the involved actors must be active and coordinated in a mutual dependency, and flaws in this collaboration have been shown in many real-world cases to result in inefficient outcomes [13]. Several factors need to be addressed for effective collaboration: technologies for supporting the COP, knowledge of each other's responsibilities and tasks, and establishment of common situational understanding [14]. However, without key information concerning the emergency event, cooperation is not a sufficient solution [15]. With more supporting organizations to be connected, the complexity of the communication increases. Undoubtedly, this is affected by information needs and prioritization challenges, and accordingly makes information sharing in such complex networks a problematic task.

The front line includes the first responders that address the situation based on their professional expertise, known as the "knowledge by acquaintance." The supportive organizations at the tactical and strategic command and control structure are the administrative executives who formally provide direction and make decisions with potential long-term consequences, known as the "knowledge by description" [16]. Insufficient key information results in situational uncertainty and henceforward decision-making errors with possibly destructive consequences [8] such as escalation of quickly developing incidents.

Universally, emergency management is divided into four phases: *mitigation, preparedness, response*, and *recovery* [17]. Extreme weather events tend to hit society with cascading effects by threatening human lives and damaging critical infrastructure. The first hours of such events are colored by chaos and complexity, and an effective operation in this critical timeline is crucial for outcome success. Therefore, the focus in this article is on the *response* phase.

In Norway, like many other countries, the emergency response system consists of several teams from different organizations (e.g. first-responders including operative units and emergency dispatchers in the command and control centers (C3), municipalities, civil defense, red cross, and the county governor) operating as a three-tiered hierarchical command and control structure (C2S) [18]. This structure illustrates the management levels (Figure 1). For example, the operational C2S is defined as the first responders working on the scene, the tactical C2S is the local incident management teams supporting the actors on the scene, and the strategic C2S is the stakeholders working at the regional, state, or national level [19,20]. Literature refers to the different levels as the front line (operational level) and the remote response network (tactical/strategic C2S) [9].

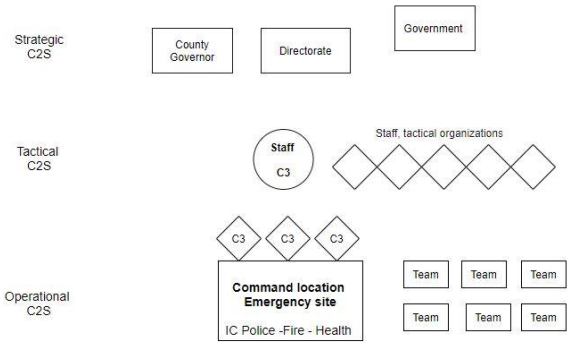

Figure 1: The three-tiered command and control structure (C2S)

2.1 Technologies for supporting the COP

Without technologies as a platform for collecting and sharing information during emergency operations, the emergency management process as we know it today would be impossible. However, the effectiveness of the technology is still determined by

several factors such as system flexibility, interoperability across the involved organizations, knowledge on how to use the systems, and infrastructure vulnerability [18].

Although there is no univocal definition of a COP [22,4,], it is largely framed as a technical system that aims to support the processes of decision-making [5] and collaboration between the different command and control structures [22]. It is illustrated in the literature as an efficient solution for information sharing and hence supports the stakeholders in building an adequate situational awareness (SA) [23] during emergency operations [5]. The COP also prevents a lack of information by making operational information accessible to the involved stakeholders. Therefore, the COP can be seen as an "information warehouse" [24] where the information is stored and available for stakeholders to collect organization-specific information. The COP originated from the military context as a "centralized information display system" [25] and has further been defined as a single identical display of relevant operational information shared by emergency management practitioners [6]. This information can be transferred between the involved organizations through the COP as long as the syntactic differences and dependencies between the stakeholders are known. As the emergency event evolves, the differences and dependencies become blurred resulting in different semantic interpretations and the need for pragmatic negotiation.

2.1.1 Public safety radio network. Handheld radio networks are frequently used for interactive communication between different stakeholders in crisis operations. Stakeholders use different channels depending on their roles and information needs [18]. The Norwegian Public Safety Network (NPSN) was implemented in 2015 and replaced all other verbal communication systems in the first responder agencies. Other organizations beyond the first responders have since been connected to the NPSN, including non-governmental organizations, many municipalities, county governors, private critical infrastructure organizations, and several other public resources. As of May 2021, there are 59,517 subscribers to the NPSN [26]. The terminals are GPS traced. One of the most important functions in the NPSN for multi-organizational communication is the ability to set up different call groups or "digital rooms." It is possible to set up several call groups, both agency-specific and cross-organizational, during one emergency operation [27]. Although user surveys show that the stakeholders are satisfied with the NPSN [28], it is not flawless. On the night of December 30, 2020, a landslide occurred in Gjerdrum, Norway, destroying several apartments and houses and killing 10 people. The NPSN was frequently used in the emergency operation, but due to the high traffic in many different call groups, the base coverage was insufficient, and the users experienced blocked lines, and the actors could not access their call group.

The Norwegian government stated in 2014 that organizations beyond the core users (e.g. first responders) must have the opportunity to use the NPSN. However, this involves an application for access and a fee. According to the provider of the NPSN, the adoption and usage of the NPSN in these organizations is varying. The resulting problems occurring are exemplified in the management of the Viking Sky cruise ship accident outside the coast of Norway in 2019. The evaluation report documented that the lack of participation and access to the NPSN resulted in deficient communication during the operation, making it challenging to build a common situational understanding.

The communication in the NPSN is regulated by a set of union regulations that consists of expressions (e.g. "understood", "repeat", "received") to avoid misunderstandings, reduce the length of messages, and decrease disturbances [27].

To secure who gives what information to whom, there are several heuristic rules in the form of acronyms, a schema following a pre-defined template [21]. Some examples are MIMMS [29], METAFOR, and HENSPE [21] These structures are not a part of the NPSN regulations. No structure for information sharing includes the three-tiered C2S in a complex multi-organizational emergency operation.

3. Common situational understanding

All the stakeholders involved in a crisis operation work together to reach the multiteam overall goal of saving lives and reducing damage. For this to be successful, it is crucial to build and maintain a common situational understanding, and effective communication for coordinated decision making [25]. On the individual level, the stakeholders must have adequate situational awareness (SA) for their agency-specific tasks. The concept of SA is defined by Endsley (1995) as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and a projection of their status in the near future." In a situation, there are several shared SA elements between the different stakeholders, which is defined in the literature as team SA [23]. Thus, it is not enough that one stakeholder knows an important SA element if it is important for several of the team members. At the operational C2S, the shared SA element can for example be smoke development. All first responders would then need to

understand how this will affect their tasks and the other first responders` tasks for successful team performance. The smoke development can also be important for the tactical C2S, and would thus be a shared SA element that needs to be communicated. However, at the strategic C2S, the smoke development might be less relevant and could distract the actors` attention from their main tasks [30]. The idea of common situational understanding requires all the involved organizations to develop and maintain an adequate information position so they can develop a shared situational overview [9]. To achieve this, the involved organizations must be aware of each other`s information needs [28] and share SA elements if it is a part of other organizations' SA requirements. However, even if stakeholders hold important SA elements, it is often challenging to know when, how, or with whom to share it [31].

All the involved organizations at the different C2S will mainly focus on their own information needs to make decisions. For example, the stakeholders at the operational C2S make decisions based on "knowledge by acquaintance" when they operate in dynamic and continually changing conditions. This requires real-time reactions [11] where the actor does not have the time to compare alternatives. This is called the Recognition-Primed Decision (RPD) model [32], where the actors react to their professional experiences and act in a way that they "know" will aid the specific condition. This is based on the identification of critical cues through professional assessment of the situation, evaluation, and implementation of an action. The tactic and strategic C2Ss have an important role in supporting the activities at the operational C2S [19] and have the time to make decisions based on descriptions and checklists.

Since the stakeholders within the three-tiered C2S have different perspectives and information requirements for decision-making, the decision-making processes have different logic. Team sensemaking is defined as "the process by which a team manages and coordinates its efforts to explain the current situation and to anticipate future situations, typically under uncertain or ambiguous conditions" (Klein et al., 2010, p. 304). If team sensemaking succeeds, it seems to be an important implication for common situational understanding, as it stresses the differences in assumptions and helps stakeholders to understand each other's needs and constraints [4].

Muhren and Van de Walle (2010) identified three activities in the information and communication exchange process that were important for sensemaking among emergency stakeholders: (1) noticing, (2) interacting, and (3) enacting. Firstly, the actors must notice the important cues in the environment using both formal (e.g., inter-organizational structures) and informal channels (e.g., personal contacts). Secondly, the actors interact with others to update their situational understanding by staying informed, verifying and negotiating the information. Actors also interact with others to reflect on their decisions, often with a limited number of tools (such as the mobile phone) due to the time limits in emergency operations. Finally, actors must communicate to enable action [33]. This can be for example alerting the operative units to respond to a specific consequence of the emergency. Because stakeholders make sense of situations differently, it is important to acknowledge the need for negotiation in information sharing processes to achieve collective sensemaking.

4. Methods

The empirical basis for this study includes interviews of 33 Norwegian emergency management stakeholders from different levels of the command and control structures (Table 1). In addition, a survey from a multi-organizational exercise organized by the INSITU project [1] focusing on common situational understanding was used to supplement the interviews (N=29). The respondents of the survey used the NPSN for verbal communication in a tabletop exercise involving three large forest fires occurring simultaneously in different areas of Southern Norway. A survey consisting of 28 questions regarding the use of NPSN was sent out to all participants directly after the exercise. 29 participants had used the NPSN and answered the survey. Both the interviews and the survey were conducted by the author of this paper.

4.1 Interviews

Table 1 presents an overview of the interviewees. The interview guide was based on transcriptions of audio logs from a real forest fire in South Norway in May 2020. The author listened and transcribed all telephone and radio communication between involved stakeholders from the first hour of the operation from a fire C3. The communication was presented in the interview guide as an objective summary (due to confidentiality) of the information exchange between different actors. Some examples of communications from the beginning of the incident are *1. Location clarifications. 2. Emergency event – fire; what is burning - bushes. 3. Possible time since the origin. 4. Fire development. 5. Possibility to extinguish the fire. 6. Wind direction.* For each information-sharing sequence (emergency dispatcher talking to the caller/lay bystander or other stakeholders), different questions were asked related to the information. For example, if their organization should be involved at that particular phase, they were asked about who they

would contact, decision-making, the use of NPSN, and additional information needs.

The interview guide also had a semi-structured section with several open questions related to verbal communication in NPSN. There were also some agency-specific questions on the use of various call groups.

The interviews lasted 60–75 minutes. Fifteen interviews were conducted face to face, while 18 were online due to the escalating Covid-19 pandemic. Some of the interviews with the Incident Commanders (IC) from the first responders were group interviews (3 actors - Police IC, 2 actors - Ambulance IC, and 3 actors - Fire IC) because they usually negotiate and make decisions together at the command location on the emergency site.

Table 1: Overview of interviewees

Level of command structure	Type of organization	Number of participants
Strategic	County Governor	3
Strategic	Directorate	1
Tactical	Police C3	6
Tactical	Ambulance C3	2
Tactical	Fire C3	2
Tactical	Civil Defence	1
Tactical	Energy Company	1
Tactical	Municipality	1
Operative	Municipality	2
Operative	Police IC	4
Operative	Ambulance IC	4
Operative	Fire IC	4
Operative	Civil Defense IC	1
Operative	Red Cross IC	1

All interviews were transcribed in full, translated from Norwegian into English, coded, and analyzed in NVivo. Firstly, the data were coded into the following categories: (1) what C2S he/she represented, (2) use/experiences with the NPSN, (3) communication/information sharing structures, (4) needed information/lack of information, and (5) additional technologies. Secondly, within each communication sequence from the forest fire scenario, the coding included the following categories: (1) information needs, (2) alert of internal and external stakeholders, (3) decision making, (4) information requiring negotiation (see table 2 on how the information was structured), and (5) possible misunderstandings. Finally, the section with open questions was coded into the following categories: (1) Ideal message exchange, (2) ideal participants in the call group, and (3) reflection on different participant views. The different categories were eventually compared between the different C2S and analyzed using an inductive method. The answers from the survey were listed and coded into the following categories: (1) reflections on how to use common call groups, (2) actions/decisions based on the information flow in the common call group, and (3) benefits/disadvantages of being a part of the communication in the common call group.

Table 2: Information levels

Syntactic	Factual information that does not have ambiguous meaning
Semantic	Information that may constitute interpretive differences
Pragmatic	Information that may imply different interests between the stakeholders that must be resolved

5. Results

The results show that all three-tiered C2S depend on the same basic information to have the same understanding of the situation they are facing. First, all involved organizations need to know what kind of situation it is (for example, accident or terror) and must receive a confirmation or update after the first report/notice. Stakeholders on all levels mention that the information in the first notice is often inaccurate regarding both the incident and position. On the strategic C2S, it is often a verbal notice from the tactic C2S; on the tactic C2S it is often a call from a lay bystander, and on the operational C2S they are provided with a radio message/alert based on the first call received by the tactical C2S. Secondly, all three-tiered C2S need to know what kind of resources the event seems to demand, whether the resources are on their way, and whether these resources are sufficient. Finally, all three-tiered C2S need an objective description of the situation, i.e. the stakeholders do not emphasize their own professional opinion. All involved stakeholders must have access to such a description as a substructure for the emergency operation. Several respondents pointed out that it is important not to describe the situation based on professional perspectives at the very beginning of the situation, because of the different views and experiences of stakeholders. As an example, a respondent from the ambulance service explained how a walking victim can be described as “appears undamaged” by other agencies; however, walking around can also be a symptom of severe head injury.

Having a heuristic rule for information sharing is frequently used internally in many agencies and some multi-agency operations involving first responders.

This appears to be a constructive method for information sharing, and results from a HENSPE (ref section 2.1.1) course among first responders show that 93.4% of 1,192 participants thought that such a structure of information sharing could be beneficial in their everyday work (K. Styrkson, professional developer, The Norwegian Air Ambulance, personal communication, 21.04.2021). In the current study, the survey asked whether the respondents knew the HENSPE structure. 63% of the respondents had not heard of the structure, while 38% knew of the structure but did not use it. None of the participants used the structure.

The results of the interviews in this study indicate that there are some common information needs among the three-tiered C2S, that are important for all involved stakeholders to establish a basic understanding of the situation (Table 3). This generates the acronym IERO.

Table 3: IERO acronym

Incident	Confirmation or update/ rejection of the situation.
Exact position	Confirmation or refuting/updating the position. Clarify the GPS format.
Resources	Estimating the need for resources. Multi-organizational perspective.
Objective description	Description of the elements in the environment, i.e., civilians, victims, dangers, damage.

5.1 Information needs at the different C2 structures

The results indicate that there is a logical connection between the information needs at the different C2S, with the tactical C2S functioning as a trading zone in the middle. Several of the information needs at the semantic and pragmatic level at the strategic and operational C2S are also present at the tactical C2S.

Based on the interviews, most of the information needs at the strategic C2S are at the syntactic level. This includes continuously updating the location, the number of people injured and dead, whether there are enough resources and the level of damage to critical infrastructure. These are elements that can be in an information system that functions as a COP. However, *the level of severity, planning*, and the *operation progress* need to be negotiated. One interviewee argued that it was important for them to think strategically and be supportive of the tactical and operational C2S. Therefore, they must plan for possible future status, and based on their knowledge and guidelines, be one step ahead. However, this requires a common situational understanding of the current elements. Overall, the results from the interviews indicate that the strategic C2S requires information at the semantic and pragmatic level, which must be communicated directly from the operational and tactical C2S. This view was echoed by the answers from the survey, where the respondents from the strategic C2S pointed out that they benefited from receiving information provided by the tactic and operational C2S.

The information needs at the semantic and pragmatic level for the tactical C2S are as follows: *level of severity, planning and operation progress, real and potential threats/dangers, evacuation, need for equipment, personnel, civilian overview,* and *time perspectives.* The three first information needs are the same as for the strategic C2S. Because the tasks for this C2S are based both on professional experience and policy, the information must become closer to the actual operation, as they have staff working on the emergency site. One respondent underpinned that they have an important role in the coordination work, and assessing the real and potential threats/dangers is crucial regarding personnel security. This is echoed by another respondent who stated that personnel security has a connection to equipment and evacuation, which involves knowing the quickest way and bottlenecks in and out of the emergency site for both civilians and personnel. All of this must be adapted to the time perspective of the emergency event and the operation. These aspects must be negotiated into a common understanding across the three C2S.

At the operational C2S, most of the information needs concern the different tasks that are needed and completed. There is a great deal of information at the syntactic level; however, the stakeholders must continually negotiate their perception of the elements to maintain a common situational understanding. The respondents reported that *security, evacuation, number and condition of patients, and cross-organizational interpretation of how to handle the emergency event in general*, is information that needs to be negotiated between the involved stakeholders at the C2S. When the respondents were asked what kind of information they needed from the higher C2Ss, most indicated status on different requested resources and whether there are any dangerous elements near the emergency site were most important.

The results in this section indicate that there is a logical connection between the three C2S related to information at the semantic and pragmatic level of information sharing. However, the stakeholders must also be able to effectively share information for

noticing, interacting, and enacting in order to build a common situational understanding. The next section, therefore, presents the results concerning how to structure the verbal information exchange using a common call group in the NPSN to facilitate interactive information sharing.

5.2 Information sharing across the C2S

The results of the interviews revealed that the different organizations use various tools to share information, such as e-mail, textual logging, and NPSN. The first responders and supporting organizations are well-established users of the NPSN, but this seems not to be the case for the additional organizations. However, the results from the interviews and the survey indicate that it could be beneficial for all three C2S to have access to all the identified information needs using the NPSN. Respondents that do not use the NPSN every day, such as personnel from the municipality and county governor, said that it is difficult to organize the call groups and communication to support the more established tools such as e-mail and telephone. A respondent from the operational C2S who was not a first responder said that they had greatly benefited from common call groups. However, there was a lack of involvement from some stakeholders at the tactical and strategic C2S.

When asked whether the verbal communication in a common call group supplemented syntactic level information, the majority (90%) of the survey respondents were positive. Further, 72.4% answered that they received a high amount of relevant information that increased their situational awareness by having access to the information exchange in the call group. Additionally, a recurrent theme in the interviews was the benefit of using common call groups to build common situational understanding. Overall, the results indicate that access to a common call group is important; however, there is a need for pre-defined guidelines for different scenarios. For example, one respondent from the tactical C2S expressed that the communication usage in the NPSN is confusing and that many stakeholders have problems with the organization of the common call groups and knowing who should speak. Another respondent reported that the crisis staff must carry more radios to monitor several call groups because it is not possible to monitor several call groups simultaneously on one radio alone.

The respondents in the interviews and the survey were further asked to suggest how to structure the verbal communication for message exchange between the different C2S. The respondents from the strategic C2S indicated that they would benefit from monitoring a common call group to gain a higher level of situational awareness. In some cases, the opportunity to negotiate information would help them to be a part of the operation in a more proactive way. A respondent from the strategic C2S said that by using a common call group, they could share information in real-time in a one-to-many modus, which could improve their sensemaking of the situation. However, communication paths must be pre-defined even if the organizations have access to the same common call group. One of the respondents said that the channel between the tactical C2S and the strategic C2S is important, but often missing. For example, the county governor could have a communication path against the involved directorate, the staff at the C3 in charge, and the municipality. Further, the different organizations at the tactical C2S must communicate with each other and the staff at the leading C3. At the operational C2S, two divergent and often conflicting discourses emerged when discussing ways to structure verbal communication in a common call group. Particularly the actors from the first responders' agencies felt that their high workload meant that they did not have the time to participate in a common call group that involved organizations outside of the first responders. Other respondents (e.g., civil defense, energy company, red cross) believed it necessary to have such access. Hence, the results are somewhat conflicting between the different representatives from the operational C2S.

A majority of the respondents mentioned the importance of the communication discipline described in the NPSN regulations. This includes the expressions for avoiding misunderstandings between the stakeholders involved.

6. Discussion

In this paper, the research question asked was: *What information elements must be exchanged at the semantic and pragmatic level between the involved organizations in extreme weather events, and how can this be facilitated by using a radio network?* The inductive approach for analyzing the qualitative interviews with 33 Norwegian stakeholders from 9 different emergency management organizations indicates that the strategic, tactical, and operational C2Ss have several information needs that must be negotiated across the C2S to build a common situational understanding. In addition, some common initial information needs for building a basis for the involved stakeholders` SA were identified (the IERO structure). The sharing of these initial information needs can be structured as a heuristic rule. Using heuristic rules for information sharing is an efficient method for collecting and sharing information because

communication processes can be complicated in stressful environments. For the information sharing to be effective, the sender must communicate in a way that the information is perceived and understood by the receiving party/ies [34]. Using an operative communication structure such as the IERO concept suggested in this study can be an effective solution. For example, implementing the elements in the IERO concept as part of the initiating actions of a common procedure can facilitate the development of an early common situational understanding.

During the emergency operation, semantic and pragmatic information needs must be shared across the C2S to build a common situational understanding. To achieve this, a more mutual and dynamic communication structure is required between the three-tiered C2S, as they are dependent on each other's knowledge, planning, and operation progress. The stakeholders have different professional backgrounds and perspectives on the situation, which makes the collaboration even more complex [7]. Another important issue that must be considered is mutual trust, as this is key to facilitate effective communication [34].The academic discussions on COP often refer to the warehouse philosophy [24], which mainly includes factual syntactic information [9]. The interviewees described several semantic and pragmatic information needs that should be communicated in real-time, including updates and negotiation of information. Negotiation is important for the process of team sensemaking both vertically and horizontally among the three-tiered C2S. Since team sensemaking concerns the involved stakeholders' understanding of the current and future status of a situation [32], it has a crucial impact on the content of the shared information. The semantic and pragmatic information levels require interaction and enacting, which is important for building team sensemaking among the involved stakeholders.

The semantic and pragmatic information needs at the strategic C2S support the strategic C2S`s role to think ahead and make decisions with a long-term impact on the situation [18]. For example, the level of severity has something to do with available resources, and this is important for the strategic C2S to understand. Of course, sharing factual information is important for common understanding. However, for this to be as effective as possible, the distribution of the information must facilitate interpretations and implications for decision-making based on factual information. The tactical C2 structure appears as the most complex level regarding information needs since they function as a trading zone between the strategic and operational C2Ss. The information needs at the strategic and operational C2Ss are also found among the information needs at the tactical C2S. The operational C2S decision-making is based on the RPD model, known as "knowledge by acquaintance" [35]. This makes the sensemaking process highly based on the activity of notice [33]. This might explain the expressed need for "cross-organizational interpretations" of different situations (section 5.1). The respondents at the operational C2S underpinned the importance of the collaboration at the incident command location on the emergency site. As the stakeholders at the operational C2S usually make rapid decisions based on the recognition of familiar cues [36], it is likely that the communication between actors is a continual discourse. Based on the results, Figure 2 demonstrates how a common call group can be used for information sharing. The black arrows represent communication paths within base coverage in the NPSN, while the blue arrows represent terminals in direct mode (e.g., for use without base station coverage). This will release network resources and enable the operation group to perform without interference from other users. For example, the communication blocks in the Gjerdrum landslide operation (see section 2.2.1) could have been avoided.

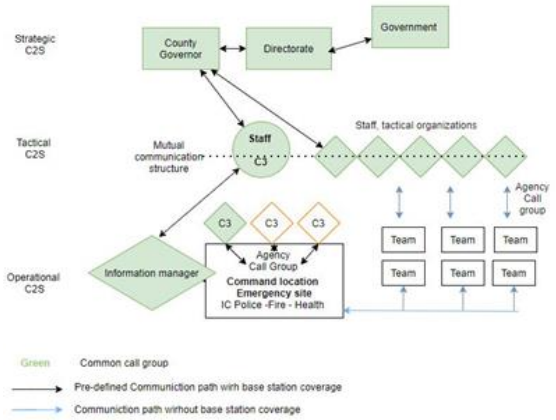

Figure 2: Using a common call group for information sharing

As Figure 2 demonstrates, the common call group is open for all the C2S. As the majority of the stakeholders from the first responders in the operational C2S are quite determined that they cannot monitor any additional call group(s), several of them mentioned the opportunity for an information manager stationed at the command location. The information manager would support the IC by communicating with the other C2S [4]. The information manager must, in this case, be aware of the different information levels and function as a trading zone between the IC and the teams working in the front line. Further, the C3 in charge of the situation (in Norway this is often the

Police) must be a part of the common call group. The strategic C2S have access to the common call group and thus have the opportunity to communicate with the different organizations at the lower level C2S. For these communication paths to be optimal predefined multi-organizational procedures must be well implemented at all C2S, and the involved actors must receive practical training in advance. The training can be an important arena for building mutual trust as it is crucial for effective information sharing [34].

7. Conclusions and further work

The results of this study show that several information elements must be negotiated across the three-tiered C2S for collective sensemaking and common situational understanding. Today, the technical and organizational structures and processes between the C2Ss are not organized as one entity, and sharing verbal information in real-time is difficult to manage. The systems used between many stakeholders are technical solutions that share factual information at the syntactic level, such as text in logging systems or e-mail with or without various attachments. This is not sufficient for information sharing at the semantic and pragmatic levels, which is crucial for building common situational understanding. This paper suggests using a secure radio network to facilitate verbal communication. With pre-defined communication paths and knowledge of what information is important to negotiate, common call groups can be an important tool in multi-organizational emergency management involving the three-tiered C2S. Further, the results add to the expanding field of the information sharing doctrine, focusing on the more implicit and complex concerns at the semantic and pragmatic level related to multi-organizational emergency management.

The practical implication of this study is the notion of the IERO structure. Using this as a heuristic/guideline can facilitate sharing common information that is needed at the beginning of an operation for building common situational understanding. Further, the emergency management organizations must consider the need for negotiation of different information elements, and facilitate the structure for communication that supplements the factual information that is provided by the COP. This can be done by developing multi-organizational guidelines for verbal status reports in a common call group (such as shown in figure 2) that support the need for negotiation on the pre-defined themes of information elements. Also, the focus on the tactical C2S as a trading zone and the role of information managers at the operational level seems to be important and necessary.

The generalizability of these results is subject to certain limitations. For instance, while the majority of other countries have only one emergency number, Norway has one dedicated emergency number for each of the different first responder agencies. The communication structures will therefore become somewhat different at the operational and tactical C2S. Despite this limitation, the study adds to our understanding of the need for information sharing at the semantic and pragmatic level, and how a public safety radio network and verbal communication can facilitate this. A greater focus on interpretations, implications, and collective sensemaking could produce interesting findings that can contribute to the discussion on COP and common situational understanding.

A question raised by this study is how the tactical C2S can facilitate a communicative trading zone between the strategic and the operational C2S without becoming the weakest link. Also, an extensive discussion on to what degree trust issues in information sharing between different organizations would affect the communication is recommended.

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