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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.

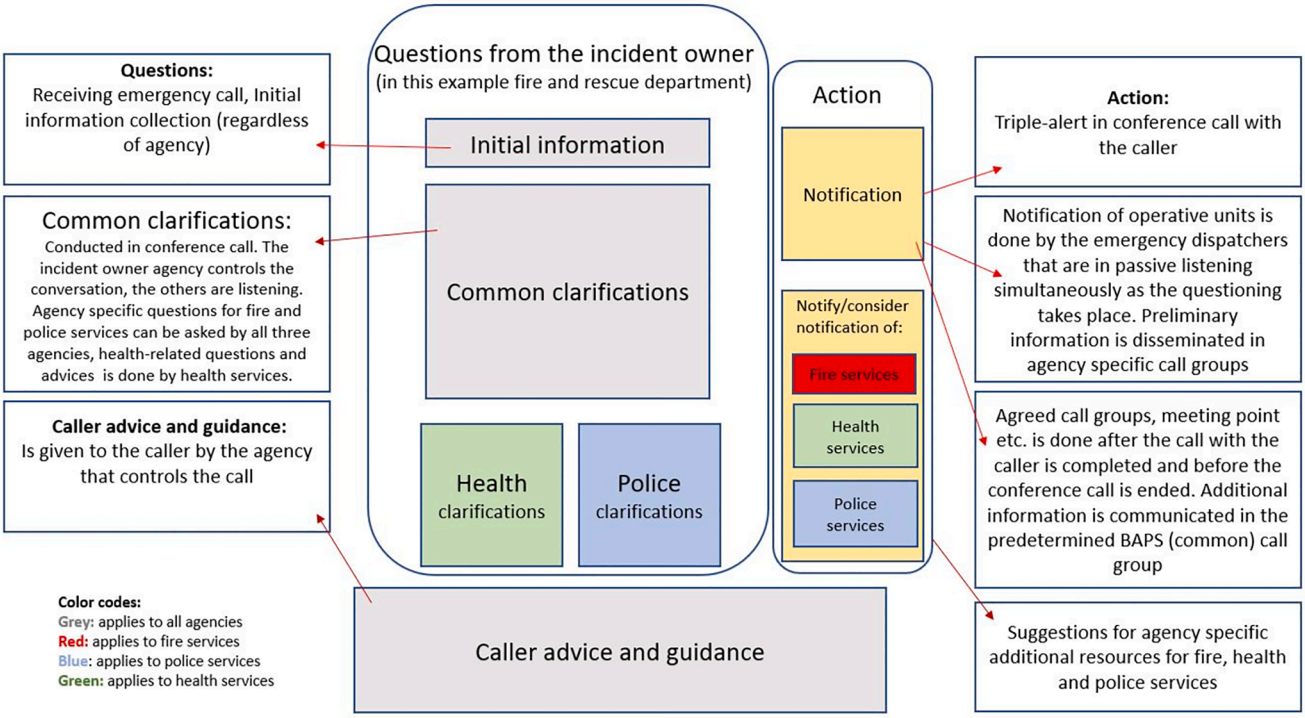

Fig. 1. Triple-alert routine for Norwegian emergency response. .
Adapted from Nakos.no (2018)

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

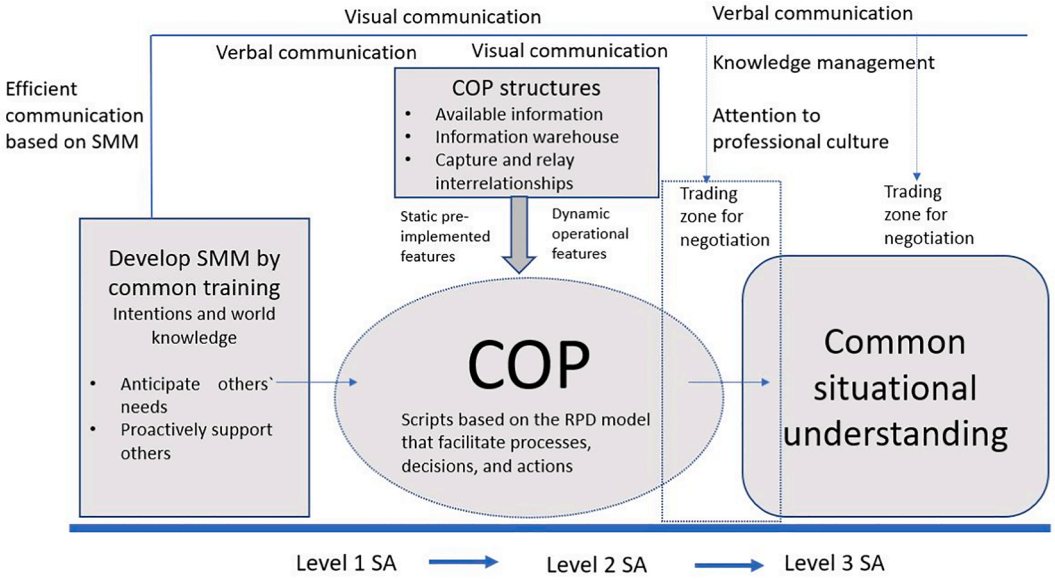

Fig. 2. A conceptual framework on how to use the COP as a baseline assessment for achieving common situational understanding.

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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