Defining Common Information Requirements for Supporting Multiagency Emergency Operations

Kristine Steen-Tveit and Bjørn Erik Munkvold

Abstract Effective response in complex emergency events requires establishing shared situational awareness among the agencies involved, through sharing relevant information and building a common operational picture (COP). However, despite its acknowledged importance, developing effective practices for such information sharing proves to be challenging. A basis for this is identifying what information is critical to share and also defining a well-functioning structure for this.

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. The study identified eight common information requirement categories for managing extreme weather scenarios. The focus on common information needs and a process for structured information sharing contributes to a more holistic perspective on cross-sectoral operations than in current practice.

Keywords Situational awareness · Common operational picture · Information sharing · Common information requirements · Multiagency emergency operations

Introduction

Climate change results in an increase in extreme weather events (Stott, 2016), such as floods, landslides, large-scale forest fires, and damaging storms. Emergency management related to such events tends to be complex because of cascading effects, threatening human survival, and causing damage to property and critical infrastructure. These events often hit critical functions in society, such as roads, elec-

K. Steen-Tveit (✉) · B. E. Munkvold
Centre for Integrated Emergency Management (CIEM), Department of Information Systems, University of Agder, Kristiansand, Norway
e-mail: kristine.steen-tveit@uia.no; bjorn.e.munkvold@uia.no

H. J. Scholl et al. (eds.), *Disaster Management and Information Technology*, Public Administration and Information Technology 40,
https://doi.org/10.1007/978-3-031-20939-0_14

tricity, and telecommunications. Operational response to natural disasters requires coordination with organizations beyond the 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 phase is crucial for the outcome. These operations require effective collaboration and information sharing in order to reach common goals, such as saving lives and reducing damage. Because of several heterogeneous information needs among the organizations involved, it is challenging to determine what information needs to be shared (Bharosa et al., 2010), which represents a bottleneck for collaborative efforts. The literature on multiagency crisis management emphasizes the importance of a common operational picture (COP) for the purpose of collaborating and sharing information (e.g., Bunker et al., 2015). The COP is intended to support the actors' development of shared situational awareness (SA) (Comfort, 2007; Endsley, 1995a). However, there is still a need for more in-depth analysis of what information elements need to be shared in such a COP for supporting multiagency operations in different contexts and what structure could be applied as the basis for this information sharing.

This chapter defines common information requirement categories for multiagency crisis management as a basis for establishing a COP during extreme weather events. Moreover, it presents a structure for sharing this information based on current practice among Norwegian first responders. The study focuses on managing extreme weather scenarios in the acute phase and is based on data collection in first responder agencies (fire and rescue, police, and medical services) and municipalities. The findings presented is thus intended to contribute to more systematic and effective information exchange in multiagency emergency response.

The next section presents a brief summary of relevant research and practice related to the concepts of SA and COP. This is followed by a description of the research approach, comprising qualitative interviews and a web-based survey. The findings from the data analysis are then presented and discussed, with conclusion and implications in the final section.

Related Research

Situational Awareness and Common Operational Picture

Collaboration is emphasized as a critical success factor in complex emergency management operations (e.g., Berlin & Carlström, 2014; Kapucu, 2008), such as multiagency management of extreme weather scenarios. However, information sharing among emergency response organizations also implies several challenges due to different disciplinary traditions, work practices and culture, lack of understanding of mutual information needs, and limited interoperability for the technology support (e.g., Bharosa et al., 2010; Comfort, 2007; Munkvold et al., 2019; Wolbers & Boersma, 2013; Steen-Tveit & Munkvold, 2021).

Situational awareness is considered a key element in emergency management (e.g., Cak et al., 2019; Dilo & Zlatanova, 2011; Endsley, 1995a). SA is 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, 1995a, p. 287). This definition refers to three hierarchical levels of 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. 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 elements in level 1 SA and the professional's ability to form patterns with that information, which leads to level 2 SA (Endsley, 1995a). At this level, the firefighter would understand that the wind direction, location, and topography indicate certain features about the situation. Some professional experience is required to be able to relate the elements in level 1 SA to the relevant goals and thus achieve level 2 SA. Level 3 SA is the highest form of SA, which involves the ability to project the future status of the situation. For instance, based on the two previous SA levels, the firefighter understands 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 & Wiggins, 2019). SA is associated with cognitive capabilities such as attention, perception reasoning, and working memory (Cak et al., 2019).

Scholarly articles present the concept of COP differently, for example, as an information system that enables information to be presented in a visual form (Luokkala et al., 2017), a continuously maintained description of a situation (Norri-Sederholm et al., 2017), a display of relevant operational information (Karagiannis & Synolakis, 2016), or a checklist of the characteristics in a certain situation within a geographical area (Wolbers & Boersma, 2013). Whether the COP is a process, a product, or an operating environment remains undefined.

Regardless of the different characteristics, an identification of the common information needs in particular scenarios is a required basis for building a COP. However, as long as the different organizations are characterized by different disciplines, tasks, goals, and working modes, a COP still 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 & Johansson, 2010), and a comprehensive COP supports building a common situational understanding. However, it is important to avoid an "all information to all people" approach (She et al., 2019), which will result in information overload through dissemination of redundant and irrelevant information (e.g., Ben Lazreg et al., 2018; Laakso & Palomäki, 2013). Humans have limited capacity to hold information available for processing, referred to as the working memory (Lauria et al., 2019). Thus, information overload complicates decision-making and creates simplified mental models (Van den Homberg et al., 2018).

Borglund (2017) acknowledged the COP as a selection of the important parts of the information available to actors. Based on this, the COP is the result of both static and available dynamic information analyzed by the different actors involved and thus their SA. They must then decide what information needs to be shared and what is irrelevant to the collaborating parties. By further drawing on the COP concept, Berggren and Johansson (2010) suggested that the COP is a geospatial 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. This is supported by Johansson et al. (2013) who argue for the relevance of the ability to localize objects in the terrain of emergency management.

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). A GIS uses custom symbols to display relevant operational information, such as location, topography, infrastructure, and different resources (Karagiannis & Synolakis, 2016). However, many emergency management services do not have access to a common GIS interface because they use different support technologies with lacking interoperability (Opach et al., 2020). 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 et al., 2013; Steigenberger, 2016).

The SA of the involved actors is a basic component for the outcome of agency-specific tasks and goals but is also a central source in establishing the COP. The involved organizations require their own SA elements; however, even if the team members hold different roles in the operation, there is often an overlap in what information they need (Endsley, 1995b; Sorensen & Stanton, 2016). Such shared SA elements must be communicated among the involved stakeholders and require knowledge on what information the team members should not keep individually. This can be briefly illustrated by the first responders' communication with each other and their respective command and control centers (CCC). As Fig. 1 shows, the three first response agencies (police, fire and rescue, and medical services) need

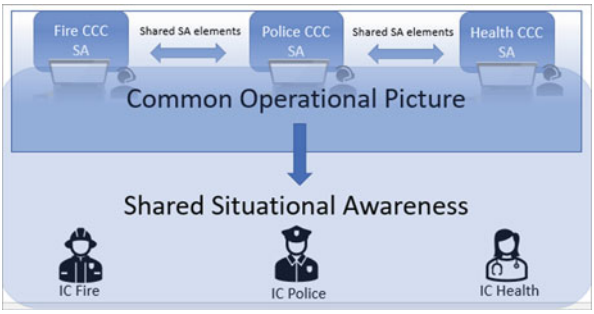

Fig. 1 Agencies' SA and communication of shared SA elements to create a COP and shared situational awareness

to build SA and communicate the shared SA elements with each other in order to establish a COP. The sharing of the common SA elements constituting the COP enables the stakeholders to develop shared situational awareness, implying that the involved stakeholders "understand a given situation in the same way" (Perla et al., 2000, p. 17).

Current Information Sharing Practice

First responders have a long tradition of collaborating on the emergency site. The first responder to arrive at the incident site provides other stakeholders with a "window report" in the Norwegian Public Safety Network, which is a common platform for collaborative communication. For the first response agencies, 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 & Gao, 2010). 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 (Fig. 2) used by the Swedish Police (Borglund, 2017). This provides information about *place* (location), *direction* (short description of what is going on), *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 CCCs for police, fire and rescue, and medical services implemented new procedures for common questioning of callers in nine different cross-sectoral scenarios (Dreyer, 2019). However, this strategic way of information sharing is limited to internal use for the first responder services and does not include other external organizations involved in emergency management. In joint operations, where organizations besides the first responders are participating, the need for information sharing includes other actors besides the operational units and their associated CCCs. For example, in extreme weather events, municipalities play a central role as they are tasked with safety at the local level and are thus an important part of the emergency management system (Civil Protection Act, 2010; Regulation on municipal emergency duty, 2011). A Norwegian project called

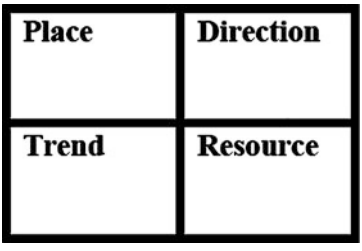

Fig. 2 The Gothenburg Window (Borglund, 2017)

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 municipalities. Other international studies have shown that there is a lack of shared protocols for communication between agencies (e.g., Bunker et al., 2015). A functional information sharing process can contribute toward building a COP between the operational units, with their associated CCCs, the municipalities, critical infrastructure providers (e.g., energy sector, road services), and other relevant organizations that must also act within their areas of responsibility. Cross-sectoral processes simplify communication, as exemplified by the structured "window report" procedure for mutual information sharing with prioritized content.

Research Method

As there exist few established procedures for information sharing between the emergency response organizations focused, an exploratory study was conducted to identify common information requirements related to extreme weather events and to investigate a possible information sharing structure based on the window report. The study involved two rounds of data collection, described in the following.

Data Collection on Information Requirements

The first round of data collection involved semi-structured interviews with nine experts from first response agencies and municipalities. In addition, a survey was sent to six experts, including two first responders and four representatives from three additional stakeholders that can be characterized as support organizations as they are not responsible for handling the crisis themselves. Table 1 specifies the interviewees and survey respondents in the first round of data collection.

The informants from the first response organizations were either recruited by their leaders following a request from the first author or contacted directly based on existing relations. The interviews were conducted in the informants' workplace. Several of the informants from the first response agencies demonstrated their working process by means of a tour and gave an introduction to their information systems as well as how and when these were used. In addition, the first author could also build upon 10 years' previous work experience as a medical emergency dispatcher, which resulted in good rapport with the interviewees.

The interviews lasted between 45 min and 1 h and were based on a semi-structured interview guide. The interview guide focused on the informants' work practices related to complex events requiring multiagency collaboration, using a forest fire scenario as example. The questions were related to the structures or procedures used to collect information on the emergency, with whom and how they share

Table 1 Overview of respondents for first round of data collection

Organization	Role	Data collection
Fire and rescue services A	Emergency dispatcher	Interview
Fire and rescue services A	Shift leader	Interview
Fire and rescue services B	Professional development	Survey
Police services	Emergency dispatcher	Interview
Police services	Emergency dispatcher	Interview
Medical services A	Head of section, acute medical Communication services	Interview
Medical services B	Professional development in acute medical communication services	Survey
Municipality A	Emergency coordinator	Interview
Municipality B	Emergency coordinator	Interview
Municipality C	Emergency coordinator	Interview
Municipality D	Emergency coordinator	Interview
Municipality E	Head of the preparedness section	Survey
Ministry of Justice and Public Security	Director	Survey
County governor	Assistant director	Survey
Civil defense	Head of district	Survey

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. The main purpose was to learn about the organizations' processes for information sharing and identify common information requirements. All interviews were recorded and transcribed in full.

In order to collect further common information requirements intended for extreme weather scenarios, experts in several emergency management organizations were contacted. These informants received a link to a web-based survey with descriptions of storm and flood scenarios and were asked to write their information requirements in the specified fields. The informants represented first responders as well as municipalities and support organizations. The information requirements from the support organizations were collected in order to identify possible differences between their requirements and those of the first response organizations.

The data from both the interviews and the survey were coded and analyzed in NVivo (QSR International). The answers were categorized based on the focused scenarios (e.g., flood, storm, and forest fire) and were further classified into information requirement categories using an inductive method. For example, when an informant said, "which area is affected by the forest fire," this was classified into the information requirement category "location." Similarly, roads, energy grid, and networks were classified under "critical infrastructure." Finally, the information requirements were compared, and the common requirements were determined and described.

Table 2 Overview of respondents for the second round of data collection

Organization	Role
Fire and rescue services A	Emergency dispatcher
Fire and rescue services B	Incident commander
Medical services A	Emergency dispatcher
Medical services A	Incident commander
Medical services A	Incident commander
Police services A	Emergency dispatcher
Police services B	Incident commander
Police services B	Incident commander

Data Collection on Information Sharing Structure

In the second round of data collection, interviews of eight first responders were conducted for investigating how information sharing could be supported by using a window report structure such as the Gothenburg Window (Fig. 1). Both emergency dispatchers and incident commanders were included, as they are the key actors in window reporting (see overview of respondents in Table 2). The questions focused on the respondents' experience with the use of window reports, what information these reports should ideally include, and possible variation in this between the different first response organizations. The data analysis was conducted in NVivo and included codes such as "window report content", "window report sharing structure", and "views and differences between the organizations."

Some of the interviews were conducted physically, while some had to be conducted online due to the Covid-19 pandemic. The informants were either recruited by their leaders following a request or contacted directly based on existing relations.

Results and Discussion

This section presents the results from the data analysis related to common information requirements and structure for information sharing and discusses the implications of this.

Common Information Requirements

From the data collected, eight common information requirement (IR) categories for sharing were identified, as presented in Table 3. The information requirement categories contain static and dynamic information. The static information remains the same throughout the incident, for example, the origin of a fire will remain the

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, and 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

same, while the location of an operative resource is changing. However, elements in critical infrastructure such as roadblocks can be both static and dynamic as they either can be permanent or eliminated/moved.

In the following, the information requirement categories are introduced in more detail.

Location (IR 1) includes information on the scope and exact position of the important locations. This can be the coordination point for the incident commanders from the first response agencies, a meeting place for operations units, and support organizations or representatives from the municipality. The organizations interviewed did not have access to the same GIS interface, which sometimes results in spending a considerable amount of time explaining locations to the collaborative organizations. As stated by one informant, "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 lack of information sharing relating to the position was specifically stated in the interviews. And the possible benefit was documented by two of the first response agencies that actually 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: "It [shared position in GIS] saves us a lot of time when you don't have an exact address." This indicates that a common GIS interface would be beneficial for creating a COP concerning emergency locations, as emphasized by all the informants. 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 assessing and mapping the possible impacts of the scenarios.

Critical infrastructure (IR 2) concerns critical societal 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 vulnerable 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 didn't know how many patients have received a COPD apparatus [breathing apparatus] that needed to be refilled (. . .). How should we know this? They [the patients] were sitting and calling someone and worrying about the electricity being gone. So, this was just chaotic, so to speak." This 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.

Information on possible victims (IR 3) is important for several reasons. First, the first responders must prepare medical treatments and search and rescue operations for victims, both according to the scope of the incident and relating to specific conditions such as burns and trauma injuries. 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 task is to keep people informed. The extent of damage, especially when it comes to injuries, is of great interest to the public.

Evacuation possibilities (IR 4) is connected to IR 3 but also concerns the total number of people affected, 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 category in the sense that the location of the evacuation spot or center must be determined.

Resources (IR 5) includes several aspects, as presented by the informants. For instance, resources can be the operational units (e.g., vehicles) of the first responders involved. Another category of resources has to do with different supplies, aid, and support that can be used when needed. 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."

Weather forecast (IR 6) is crucial for planning the next steps of the operation. For instance, wind direction, rainfall, and wind speed are important information elements in preventing and handling the consequences of extreme weather.

Critical buildings (IR 7) includes information on important buildings such as building plans, materials, storage, and hazardous materials, both to support handling the operation and preventing damage. Examples of such buildings include nursing homes, hospitals, and evacuation centers, all of which are connected to IR 4.

Situational development (IR 8) is an interconnected information requirement category, which concerns weather forecast (IR 6), possible victims (IR 3), and resources (IR 5). In addition, this category covers other projections on how the situation might develop. According to an informant, "How we comprehend the situation, if it's a threatening situation posing a danger for others involved." In the "window report" structure, IR 8 can be seen as an information category in itself because it covers information that needs to be shared among all the involved actors.

Our findings from the analysis of the different information requirements corroborate previous research (e.g., Bunker et al., 2015) stating 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. Information overload here becomes an issue, in addition to the fact that the consideration of all information needs would require a COP that is difficult to build and maintain. Some of the information requirements presented in Table 3 may therefore apply with different levels of detail for the different organizations, in addition to their agency-specific information requirements for supporting their individual tasks and goals.

The Window Report Structure for Information Sharing

While the actors involved in multiagency operations each have some agency-specific goals, collaboration is a critical success factor in the achievement of common goals. In order for this collaboration to be successful, it is crucial that the common

information requirements are shared with the relevant stakeholders and not remain within the agencies or individual actors (Sorensen & Stanton, 2016). A study on building SA in a fire emergency response demonstrated the importance of information collection for this, 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 the cross-sectoral 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 multiagency network, appearing as an effective and prioritized structure. During the data collection for this chapter, several of the actors referred to the window structure when asked about how they build a COP, e.g., "I really like what we call the "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." This structure for information sharing among the relevant agencies can therefore be seen as the foundation of the COP and shared SA.

Several informants still pointed to the need for improved structure for such window reporting. One informant argued that "ideally, one should follow a pattern for this type of situation reporting" (emergency dispatcher, Police), and another said, "It must be structured with short, concise, and time-critical information" (emergency dispatcher, Fire). Interestingly, there were differences in the results between the emergency dispatchers and the incident commanders regarding the window report structure. The emergency dispatchers called for more structure in the window reports provided by the incident commanders, while the incident commanders were reluctant toward this. For example, one incident commander stated that "You feel like you want to start doing something, then you have to talk [in the common call group] and there will be a delay" (incident commander, Police). Nevertheless, all the informants reported that there is a need for an improvement in the window reporting structure. The results indicated that the difference between the incident commanders' and emergency dispatchers' views can be explained by the possible additional workload from such "procedure-based tasks" for the incident commanders who already have several urgent tasks they must perform at the incident scene. However, the lack of information in the window report may also result in additional inquiries from the CCC: "We often have to ask for information (. . .) but sometimes we know that they [the incident commanders] have an insane workload" (emergency dispatcher, Police). Taking this into account, a streamlined structure might save time for all the stakeholders involved. An incident commander suggested that "if we could implement a procedure-based window structure reporting (. . .) into our certification, then I'm very in favor of it. But it has to be learned, people have to try it before they have to do it in real events" (incident commander, Health).

When asking the informants about the ideal content of a window report, four categories emerged: *location*, *status quo*, r*esources*, and *projection*. These categories can be associated with the categories in the Gothenburg Window, however, they are more descriptive for the content in the categories. For example, location corresponds to place (but appears to be more specific with including coordinates), status quo

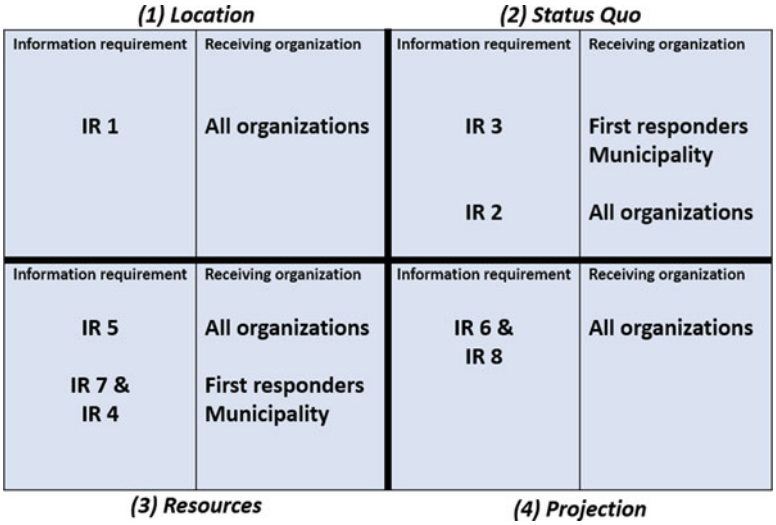

Fig. 3 A window report structure for sharing common information

relates to direction, projection relates to trend, while the resources category appears the same.

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. The common information requirement categories can be placed in the window and serve as a structure for indicating what information must be shared and to whom (Fig. 3).

Location is the first square in the window report 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. Further, the stakeholders need to confirm that the location is accurate: "we must confirm that it is the address that the others also have received, that there is a common understanding of the location. Also, possibly if the road is slippery before the incident scene, for example, obstacles or something" (incident commander, Health).

Status quo functions as a confirmation of the emergency event itself. For example, an emergency dispatcher states that "we often experience that the first information [i.e., from the bystander that reported the emergency by calling the emergency number] does not correspond to reality at all" (emergency dispatcher, Police). Status quo involves SA because it is a short objective description of the situation. Because a "window report" is a first impression description, the status quo 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. There are several pitfalls in projecting the status of patients, and injuries 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 status quo square.

In the *resources* square, the first stakeholder on the incident scene must provide an update on the resources. An incident commander states that "we must inform what resources are alerted and coming, and we need a good feedback from health and fire as well, what resources they have sent" (incident commander, Police).

The last square in the window is *projection*, 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.

Conclusion

This study has identified eight information requirement categories common for first responders and other organizations involved in emergency management, which are necessary for building a COP and shared situational awareness when handling extreme weather scenarios. 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 the common information requirements that need to be shared during an operation. The working methodology consists of how to share the relevant information. This chapter presents the "window report" structure as an example of how to effectively share both static and dynamic operational information (i.e., location, status quo, resources, and projections). Together, the common information requirement categories and the window report structure can contribute to more systematic and effective information sharing practices in multiagency emergency operations.

While our study has focused on common information requirements for handling extreme weather events, this also has relevance for other crisis scenarios. The "window report" structure would here serve as a template for which information categories need to be shared and with whom, in different types of crises. Further research is needed on how to integrate this mode of operation in the work practices of the organizations involved in the joint response and on developing technology support infrastructure that allows for effective and seamless information sharing.

Acknowledgments This study was made possible through the engaged participation of several emergency management stakeholders in Norway. The authors would like to thank all the informants for their time and assistance. The findings, arguments, and conclusions in this chapter are the result of the authors' understanding. The study was partly funded by a grant from the Research Council of Norway (the INSITU project, grant # 295848).

References

Ben Lazreg, M., Chakraborty, N. R., Stieglitz, S., Potthoff, T., Ross, B., & Majchrzak, T. A. (2018). Social media analysis in crisis situations: Can social media be a reliable information source for emergency management services? In *Proceedings of the 27th international conference on information systems development (ISD 2018), Sweden*.

Berggren, P., & Johansson, B. J. (2010). Developing an instrument for measuring shared understanding. In *Proceedings of the 7th international conference on information systems for crisis response and management, (ISCRAM 2010), USA*.

Berlin, J. M., & Carlström, E. D. (2014). Collaboration exercises - the lack of collaborative benefits. *International Journal of Disaster Risk Science, 5*(3), 192–205.

Bharosa, N., Lee, J., & Janssen, M. (2010). Challenges and obstacles in sharing and coordinating information during multi-agency disaster response: Propositions from field exercises. *Information Systems Frontiers, 12*(1), 49–65.

Borglund, E. A. (2017). The role of artefacts in creating a common operational picture during large crises. In *Proceedings of the 14th international conference on information systems for crisis response and management (ISCRAM 2017), France*.

Bunker, D., Levine, L., & Woody, C. (2015). Repertoires of collaboration for common operating pictures of disasters and extreme events. *Information Systems Frontiers, 17*(1), 51–65.

Cak, S., Say, B., & Misirlisoy, M. (2019). Effects of working memory, attention, and expertise on pilots' situation awareness. *Cognition, Technology & Work, 22*, 1–10.

Civil Protection Act. (2010). *The Act on Municipal Emergency Preparedness, Civil Protection Measures and the Civil Defense, LOV-2010-06-25-45*. Retrieved from https://lovdata.no/dokument/NL/lov/2010-06-25-45#KAPITTEL_5.

Comfort, L. (2007). Crisis management in hindsight: Cognition, communication, coordination, and control. *Public Administration Review, 67*, 189–197.

Dilo, A., & Zlatanova, S. (2011). A data model for operational and situational information in emergency response. *Applied Geomatics, 3*(4), 207–218.

Dreyer, K. (2019). *Innføring av Felles trippelvarslingsrutiner (Implementation of triple alert routines*). Retrieved from https://kokom.no/innforing-av-felles-trippelvarslingsrutiner/

Endsley, M. R. (1995a). Toward a theory of situation awareness in dynamic systems. *Human Factors, 37*(1), 32–64.

Endsley, M. R. (1995b). A taxonomy of situation awareness errors. *Human Factors in Aviation Operations, 3*(2), 287–292.

Falkland, E. C., & Wiggins, M. W. (2019). Cross-task cue utilisation and situational awareness in simulated air traffic control. *Applied Ergonomics, 74*, 24–30.

Fredheim, H. (2017). *A new model for crisis management, OPSAM (Operation center for collaboration and preparedness). Final report from project on Concept for Holistic Crisis Management*. Oslo police, Oslo Municipality, Bærum Municipality, Asker Municipality and Oslo University Hospital.

Johansson, B. J., Hellgren, C., Oskarsson, P.-A., & Svensson, J. (2013). Supporting situation awareness on the move- the role of technology for spatial orientation in the field. In *Proceedings of the 10th international conference on information systems for crisis response and management (ISCRAM 2013), Germany*.

Kapucu, N. (2008). Collaborative emergency management: Better community organising, better public preparedness and response. *Disasters, 32*(2), 239–262.

Karagiannis, G. M., & Synolakis, C. E. (2016). Collaborative incident planning and the common operational picture. In *Proceedings of the international conference on dynamics of disasters* (pp. 91–112). Springer.

Laakso, K., & Palomäki, J. (2013). The importance of a common understanding in emergency management. *Technological Forecasting and Social Change, 80*(9), 1703–1713.

Lauria, M. J., Ghobrial, M. K., & Hicks, C. M. (2019). Force of habit: Developing situation awareness in critical care transport. *Air Medical Journal, 38*(1), 45–50.

Li, N., Yang, Z., Ghahramani, A., Becerik-Gerber, B., & Soibelman, L. (2014). Situational awareness for supporting building fire emergency response: Information needs, information sources, and implementation requirements. *Fire Safety Journal, 63*, 17–28.

Liang, S., & Gao, Y. (2010). Real-time notification and improved situational awareness in fire emergencies using geospatial-based publish/subscribe. *International Journal of Applied Earth Observation Geoinformation, 12*(6), 431–438.

Luokkala, P., Nikander, J., Korpi, J., Virrantaus, K., & Torkki, P. (2017). Developing a concept of a context-aware common operational picture. *Safety Science, 93*, 277–295.

Munkvold, B. E., Radianti, J., Rød, J. K., Opach, T., Snaprud, M., Pilemalm, S., & Bunker, D. (2019). Sharing incident and threat information for common situational understanding. In *Proceedings of the 16th international conference on information systems for crisis response and management (ISCRAM 2019), Spain*.

Norri-Sederholm, T., Joensuu, M., & Huhtinen, A.-M. (2017). Ensuring information flow and the situation picture in Public Safety Organisations' Situation Centres. In *Proceedings of the 16th European conference on cyber warfare and security (ECCWS 2017), Ireland*.

Opach, T., Rød, J. K., Munkvold, B. E., Radianti, J., Steen-Tveit, K., & Grottenberg, L. O. (2020). Map-based interfaces for common operational picture. In *Proceedings of the 17th international conference on information systems for crisis response and management (ISCRAM 2020), USA* (pp. 276–294).

Perla, P., Markowitz, M., Nofi, A., Weuve, C., Loughran, J., & Stahl, M. (2000). *Gaming and shared situation awareness*. The Defense Advanced Research Projects Agency, DARPA. Retrieved from: https://apps.dtic.mil/sti/pdfs/ADA390137.pdf.

QSR International. What is NVivo. Retrieved from https://www.qsrinternational.com/nvivo/what-is-nvivo

Regulation on municipal emergency duty. (2011). *Regulation on municipal emergency duty, FOR-2011-08-22-894*. Retrieved from https://lovdata.no/dokument/SF/forskrift/2011-08-22-894.

Schroeder, J. M., Manz, D. O., Amaya, J. P., McMakin, A. H., & Bays, R. M. (2018). Understanding past, current and future communication and situational awareness technologies for first responders. In *Proceedings of the fifth cybersecurity symposium, ID, USA*.

Seppänen, H., Mäkelä, J., Luokkala, P., & Virrantaus, K. (2013). Developing shared situational awareness for emergency management. *Safety Science, 55*, 1–9.

She, M., Li, Z., & Ma, L. (2019). User-defined information sharing for team situation awareness and teamwork. *Ergonomics, 62*, 1–41.

Solberg, S., Halvorsen, J., Urdal, A., Sørsdal, L., Aasgaard, M., Parnemann, O. P. and Eggertsson, Y. (2018) Handbook for search and rescue: System descriptions, principles and values, level 1,.

Sorensen, L. J., & Stanton, N. A. (2016). Keeping it together: The role of transactional situation awareness in team performance. *International Journal of Industrial Ergonomics, 53*, 267–273.

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.

Steigenberger, N. (2016). Organizing for the Big One: A review of case studies and a research agenda for multi-agency disaster response. *Journal of Contingencies and Crisis Management, 24*(2), 60–72.

Stott, P. (2016). How climate change affects extreme weather events. *Science, 352*(6293), 1517–1518.

Van den Homberg, M., Monné, R., & Spruit, M. (2018). Bridging the information gap of disaster responders by optimizing data selection using cost and quality. *Computers & Geosciences, 120*, 60–72.

Wolbers, J., & Boersma, K. (2013). The common operational picture as collective sensemaking. *Journal of Contingencies and Crisis Management, 21*(4), 186–199.