Map-based Interfaces for Common Operational Picture

Tomasz Opach
Norwegian University of Science and Technology / Linköping University
tomasz.opach@ntnu.no

Jan Ketil Rød
Norwegian University of Science and Technology
jan.rod@ntnu.no

Bjørn Erik Munkvold
University of Agder
bjorn.e.munkvold@uia.no

Jaziar Radianti
University of Agder
jaziar.radianti@uia.no

Kristine Steen-Tveit
University of Agder
kristine.steen-tveit@uia.no

Lars Ole Grottenberg
University of Stavanger
lars.grottenberg@uis.no

ABSTRACT

Common operational picture (COP) map-based interfaces display operational information to support integration of emergency responders. Such interfaces integrate different subsystems and present the resulting information into an overview for enabling situation awareness. Literature shows that they are often developed from non-user-centric perspectives and are defined in technological terms that are not adequately capturing the users' needs. Therefore, the aim of this particular work in progress is to get insight into the features and the role of COP map-based interfaces currently being used in Norway to (1) examine their content, functionality, and design; and (2) to understand how such displays are incorporated into the service context. This study structures the knowledge on map displays that constitute part of the COP services. Using workshop and interviews with the developers and users of existing COP map services, we identify requirements for a common operational symbology and common operational functionality to improve such map services and make them interoperable.

Keywords

Common Operational Picture, Situational Awareness, Map-based Interface, Cartographic Design, Cartographic Symbolization.

INTRODUCTION

Complex emergency operations typically require collaboration within a single command as well as between multiple actors such as police, fire department, and health department. In the management of emergency operations, engaged actors need to display operational information such as position and status of own emergency units as well as position and status of resources administrated by other emergency responders (Chmielewski and Gałka, 2009). Moreover, within specific actors, various tasks are assigned differently, to their command posts, operational leaders, as well as to their particular field teams (Björkbom et al., 2013). Additionally, various actors have different structures and are administrated differently; they also need to follow different symbol standards (Chmielewski and Gałka, 2009). All those aspects influence the way, in which information needs to be provided visually by means of common operational picture (COP) map-based interfaces.

The main task of COP tools is to combine data from different subsystems and present the resulting information into an overview for enabling situation awareness of a variety of actors during emergency operations (Björkbom et al., 2013). In 2006, McNeese et al. concluded that COPs are typically developed from non-user-centric perspectives and are defined in technological terms that are not always in the best interests of users. They identified

this issue as a critical need area (a research-specific gap) since "success results from representations and visualizations that are highly user-centric, rather than just computationally-convenient or designed strictly from a programmer's mindset" (McNeese et al., 2006:468). Although much has changed since then, mainly because of advances in information and communication technology, support of user-centric affordances through the use of commonly known symbolization and functionalities still needs efforts and investigations. As long as the individual emergency agencies work independently, with no need for common actions, problems do not exist. However, challenges arise when the agencies need to undertake collaborative efforts that require COP map-based interfaces where information need to be symbolized in an understandable way and supported by intuitive interactive functions. The research reported in this paper constitutes part of the ongoing INSITU project that focuses on supporting information sharing for common situational understanding in inter-agency operations (Munkvold et al., 2019).

Aim, research goals, and contribution

Our overarching ambition is to determine a common operational symbology and common operational functionality to be used in COP map-based interfaces. Our long-term efforts encompass defining details on symbol design as well as identifying key functionalities ensuring compatibility among the semantics and interoperability of created COP. In turn, the aim of the study reported in this work-in-progress article is to get an insight into the features and the role of COP map-based interfaces being used in Norway that support situational awareness during emergency operations. Since such objective extends the scope of a single study, we narrow it down to two specific research questions (RQs):

(1) What is the typical content (map symbols), functionality, design of a map display?

(2) How are map displays incorporated into the service context?

Our ambition is twofold. Firstly, we intend to structure the knowledge on map displays that constitute part of COPs. Secondly, through the survey on existing COP map-based interfaces and interviews with their developers and users, we attempt to identify requirements for a common operational symbology and common operational functionality to be implemented in such map-based interfaces to make them interoperable.

BACKGROUND AND RELATED RESEARCH

Situation awareness and common operational picture

In her study from 1995, Endsley identified the three levels of situation awareness. The first level is perception or sensing. At the second level, meaning is assigned to each bit of information hence comprehension is built from the observed data. Finally, the third level lets individuals project the situation implications into the future. In the first two levels data is gathered by several entities and fused to some comprehensible picture of the situation. The task of the user is then to decide actions or predict the future based on the situation picture.

Most of the situation awareness studies concern military cases (Hager, 1997; McNeese et al., 2006; Björkbom et al., 2013) where a common, real-time representation of the battlespace has always been of primary importance to commanders. Therefore, the early milestones in the 80's concerned military command posts that benefited from, e.g., the development of large group displays for visually representing tactical, operational, and strategic information to enable situation awareness (Endsley, 1995). As McNeese et al. (2006) claimed, current studies on COP map-based interfaces constitute an extension of prior work on such displays.

Actors with different tasks, capabilities, and resources have different needs regarding displaying information on COP map-based interfaces and using their functionalities to perform specific operational tasks (Friedmannová, 2010). Sometimes, the same information needs to be displayed by means of large displays or laptop screens, but also, provided in small portable devices. All those issues make combining information from several subsystems and design settings of COP map-based interfaces challenging and effortful.

COP to support emergency responders

Shortly after being introduced to military purposes, COP map-based interfaces have been successfully used to support emergency responders (Deschamps et al., 2002). However, studies that concern the needs of emergency management in general and the needs during natural hazards in particular are sparse and fragmented in the literature. For instance, McNeese et al. (2006) emphasized the necessity of developing COPs in relation to geographical data. If COPs are to support responses to natural disasters, incorporating extensive information on environmental conditions is of importance to its users since such information can potentially save more lives

(King, 2005). Information on environmental conditions is a need that is well exemplified in the Decision Support System established by the International Joint Commission to reduce the impact of future flooding in the Red River Basin in Canada and the US (Deschamps et al., 2002). With extensive geographical data, the Decision Support System resembles geographic information systems (GIS). Available thematic maps can serve as background layers to pin information to geographical coordinates and tie them to the environment. A similar role has been described by Chen et al. (2014) who argued that a mapping component displays real time operational information and combines it with GIS layers.

Not only content related issues, but also the way how collaboration between group members can be reflected in COPs has been addressed by scientists. Adibhatla et al. (2009) presented and evaluated a transactive memory system that draws upon Wegner's (1987) transactive memory theory. The theory emphasizes the role of knowledge specialization among group members in a group's ability of solving a composite problem. Collaboration between group members has also been investigated by Baber et al. (2013) who used social network analysis and agent-based modeling to explore different forms of information flow between actors. They defined two patterns – "command" and "control" that can be suited to complex emergency operations.

Implementations of command and control (C&C) within emergency management domains is shaped by societal factors and operational concerns. The Norwegian emergency management system is structured around four principles, namely responsibility, similarity, proximity, and cooperation. Together, these principles forms the basis on which C&C is exercised (Norwegian Ministry of Justice and Public Security, 2016), and diverges from military C&C structures in some key matters. Emergencies are not managed through a centralized apparatus, instead emphasizing local decision-making and delegated authority, often including voluntary resources and semi-professional rescue workers. While the police are responsible for C&C at the operational and tactical levels, emergencies can see a wide variation in participants, particularly in rural areas where available resources may be sparse (Sikkerhetsutvalget, 2016). The systematic integration of voluntary resources, coupled with a decentralized C&C structure, creates a set of challenges when it comes to ensuring that stakeholders have access to the tools and data needed to build a COP. Various software systems and lack of interorganizational data access, particularly across the professional-voluntary divide, has been among the factors limiting efficient sharing of information during emergencies (Grottenberg and Njå, 2017). These difficulties give a compelling argument for establishing a common set of dedicated capabilities across organizations – "common operational functionality" (Chmielewski and Gałka, 2009), accomplished through the implementation of software solutions, robust APIs and mechanisms for inter-organizational data sharing.

User-centric design of decision support map-based interfaces

COPs resemble other decision support tools that employ map displays. Therefore, in the design of COP map-based interfaces, developers can draw upon approaches to be used when preparing decision support geographic visualization tools (Kuvedžić Divjak and Lapaine, 2014). The latter are often designed to support specific tasks that are grouped into various task taxonomies (Zhou and Feiner, 1998; Gotz and Zhou, 2009). Such taxonomies facilitate optimizing tool functionalities since they can help assign adequate interactive functions to desired tasks to be supported, and thus, can help fulfill user needs.

Equipping map-based decision support tools in interactive functions appreciated by target users, and therefore, following the user-centric design approach, is recently a commonly used strategy (Opach and Rød, 2014). In the context of COP, good examples are the work by van Dijk (2015) and the study by Balakrishnan et al. (2009). The latter investigated the performance of specific interactive functions: a layer management function and a spatially annotated chat. Their qualitative evaluation concerned user-centric problems related to human-computer interaction to support group work and impact of geo-tools on group work.

Cartographic literacy is another aspect to be considered when designing COP map-based interfaces with user-centric approach. Such interfaces—if being well-designed—can facilitate communication of geographical information in crisis situations (Kuvedžić Divjak and Lapaine, 2014). The design of geographic background, thematic overlays, and thematic content needs to be addressed when elaborating map-based interfaces. The thematic content part, in particular, seems to be of key importance to emergency responders as it concerns event details such as affected areas, rescue squad positions and human resources in use. Therefore, establishing a common set of map symbols – "common operational symbology" (Chmielewski and Gałka, 2009), similarly as establishing "common operational functionality", can make communication between decentralized emergency officers more efficient. A good example of such efforts is an attempt to design a map key to monitor the transport of dangerous goods (Friedmannová, 2010). The resulting key is a compact system where colors and shapes are the leading attributes that knit groups of symbols together. The role of these two attributes has also been emphasized by Wang et al. (2010) who argued that they both have a strong visual impact on the map reader. Symbols for emergency maps were also analyzed by Dymon (2003) and Robinson et al. (2010). Their research

revealed that standardization evolves and needs constant adaptation and improvements.

In the following section we outline the methods applied for investigating common operation functionality and symbology, including a survey on existing COP tools in use by various emergency responders in Norway, and a workshop, interviews, and meetings with their users and designers.

METHODS

Survey on COP map-based interfaces in use by selected emergency responders in Norway

To survey COP map-based interfaces systematically, we have considered the following issues:

- Data content (map background, thematic overlays, dynamic content on-the-fly, forecasts)
- Functionality provided (supported use case scenarios)
- Cartographic symbolization

Table 1 lists the map-based tools included in the survey. The basic problem with performing a survey of web software of any kind is the continuous improvement and update of software. As a result, an already published software description often does not reflect the software's most recent version. For example, the services provided by BarentsWatch that were earlier grouped into one web tool (https://kart.barentswatch.no) have recently been divided into a number of thematic services such as "Wave forecast", "Fishery activity", and "Norwegian fish health." Therefore, we had to revisit the websites and focus on those tools that concern emergency support only.

Table 1. COP map-based interfaces included in the survey

Service name	URL	Service provider	Service producer
TransMed	unavailable	Ambulance services	Locus Public Safety
KystInfo	https://kart.kystverket.no/	The Norwegian Coastal Administration (Kystverket)	Avinet
DSB Map	https://kart.dsb.no/	The Norwegian Directorate for Civil Protection (DSB)	Avinet
Wave forecast	https://www.barentswatch.no/en/waveforecast/	BarentsWatch	Avinet
The Marine Spatial Management Tool	https://kart.barentswatch.no/	BarentsWatch	Avinet

Availability was the main condition for the selection of services. Moreover, while Avinet's solutions are freely available web tools commonly used by Norwegian emergency responders, the solutions offered by Locus Public Safety are dedicated for specific users. Therefore, the information about Locus's tools can be obtained from software demonstrations and provided documentation.

Meetings with emergency responders

Two meetings with emergency responders were conducted (Table 2) to gain a better understanding of the way COP map-based interfaces are used by the emergency responders and to gain feedback on the interfaces' advantages and shortcomings.

Table 2. Meetings with emergency responders

Date	Meeting format	Details
15-16 October 2019	Two-day workshop in Oslo	The workshop was divided into three group sessions and aimed to discuss information sharing for common situational understanding. Twenty individuals attended the workshop. They represented various agencies and emergency responders such as police, fire department, health services and the Norwegian Directorate for Civil Protection (DSB).
29 November 2019	Skype meeting	The meeting was built around a live demonstration of the COP map services in use by the Norwegian Coastal Administration (NCA). The meeting lasted 1.5 hour.

The first meeting was arranged as a two-day workshop with multiple emergency response organizations. The workshop consisted of three group sessions that employed different empirical techniques such as brainstorming and world café. In this work-in-progress we use data from the workshop's brainstorming session. The second meeting was arranged as a Skype meeting with a representative from the Norwegian Coastal Administration (NCA). A live demonstration of the map-based tool in use by the NCA constituted the basis for the discussion.

Interviews with COP software producers

Two interviews with COP software producers were conducted (Table 3) to get a preliminary understanding of how the producers try to fulfill requirements and expectations of emergency responders. Such understanding is needed to get insight into features that make COP map-based interfaces usable and useful.

Table 3. Interviews with COP software producers

Service producer	Date	Details
Locus Public Safety	14 October 2019	A representative of Locus Public Safety was interviewed by two representatives of the INSITU project. The meeting lasted 1.5 hour.
Avinet	13 November 2019	A representative of the Avinet company was interviewed by two representatives of the INSITU project. The meeting lasted one hour.

Both interviews were semi-structured, using a common thematic interview guide. Table 4 lists questions posed during the interview of Avinet's representative. Moreover, the interview with Locus Public Safety also included a demonstration of some of the company's tools. The interviews were recorded and transcribed. In this study we focus on the aspects that relate to requirements for COP map-based interfaces.

Table 4. The thematic interview guide used during the interview of Avinet's representative

ID	Question
1	Do you have an overview of the centers / agencies / emergency services that use / do not use Avinet map systems?
2	How is Avinet map integrated with other systems?
3	What are the possibilities for integration between the agency-specific map systems?
4	How is this used in the different areas?
5	How closely do you engage users during your system development? How?
6	Do you have users following up on real events / exercises?
7	What opportunities does Avinet (developers) have to work with / understand "users' situational understanding"?
8	Do you use standard map symbols? (possibly yours or existing ones)
9	To what extent do you discuss the design of map symbols with users?
10	How do you plan to develop the systems? (a) With more complex possibilities? (b) In terms of integration with other systems?
11	Can you tell about the process (opportunities / obstacles) by sharing maps between agencies?
12	What formats and standards underlie the transmission of geographical information via Avinet's systems?
13	To what extent is it possible to transfer standardized geographic information to third parties outside your system?
14	Is this considered as a relevant area of further development?
15	What advice do you have for the INSITU project regarding how map solutions can / should contribute to a common understanding of situations during crises?

RESULTS

Features of COP map-based interfaces in use in Norway

Apart from TransMed, the other surveyed interfaces have been primarily designed for planning and execution of day-to-day operations. A common feature of the surveyed tools is their rich content. The tools either directly enable displaying various map backgrounds, overlays and thematic content (in particular in The Marine Spatial Management Tool), or redirect to other sister-tools that enable displaying various map layers (the Wave forecast tool).

The tools offer functionalities typical for regular web mapping services such as layer manager (e.g., DSB Map, Wave forecast), measuring distances and areas (e.g., Wave forecast), and data filtering (The Marine Spatial Management Tool). Moreover, the considered tools enable drawing objects on a map (e.g., KystInfo) that can be next saved and shared with other system users.

The surveyed map-based tools from Avinet feature similar functionality. To some extent, they also share similar layout and design (e.g., KystInfo, DSB Map, and The Marine Spatial Management Tool) (Figure 1). The layout of Avinet's fourth considered tool, i.e., Wave forecast, has undergone modifications and redesign in comparison with the design of the company's earlier products. For example, its layer manager has been moved to the left-hand side and the legend is shown at the bottom of the interface (Figure 2).

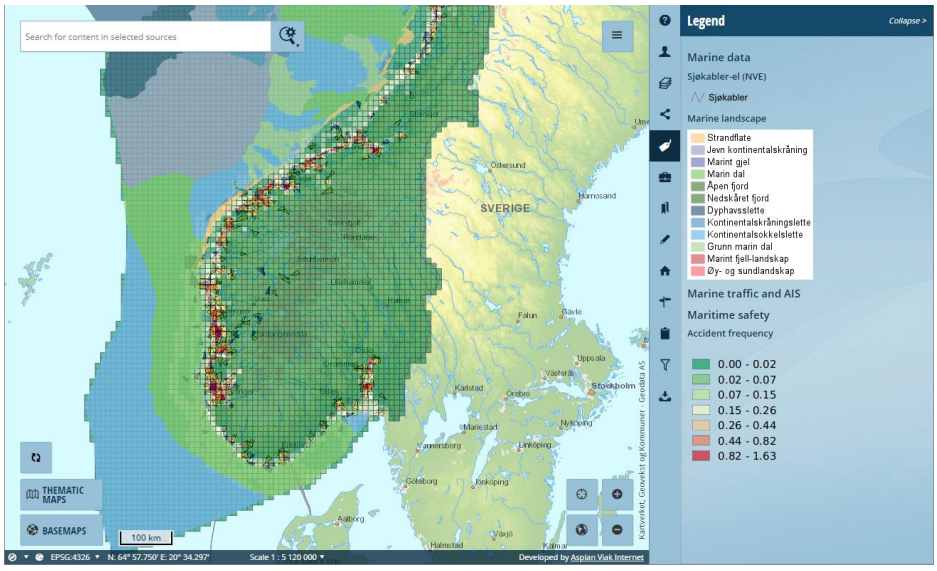

Figure 1. Kystinfo – one of Avinet's map-based tools that share similar layout and design with other Avinet products

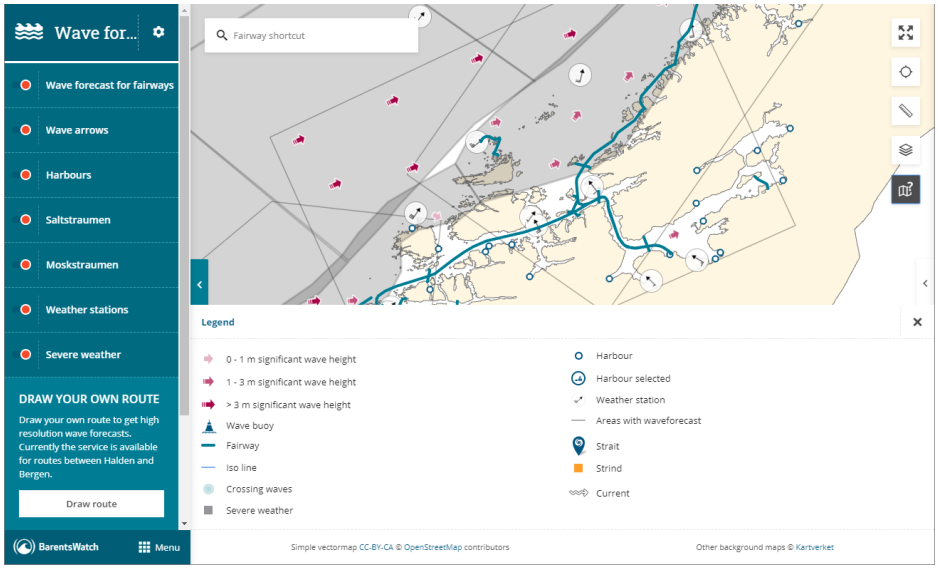

Figure 2. Wave forecast – one of Avinet's map-based tools that has undergone layout redesign

The surveyed tools use map symbols that have been inherited from their map backgrounds and thematic overlays. This causes diversity in the cartographic symbolization. Reading difficulties, i.e., problems with visual information decoding, appear if several thematic overlays are shown simultaneously. Figure 1 shows KystInfo with four thematic content layers being displayed: sea cables (sjøkabler), marine landscape, marine traffic and AIS (Automatic Identification System), and maritime safety (accident frequency). Since two of the layers, i.e., marine landscape and maritime safety, use similar colors for two of their legend categories, the map interpretation needs to be careful.

TransMed is of a different nature as it is to be used by a first-response emergency actor whose responsibilities and tasks are strictly determined by regulations and procedures. TransMed combines a map display with tables. The map shows status and positions of ambulances, various points of interests, and events, whereas the tables contain information about selected objects and communication logs. The symbology in use has been determined by the target users. However, background maps and thematic map overlays, typically retrieved as Web Map Service raster tiles, use the same symbolizations as those used by the authorities the maps come from.

Meetings with emergency responders

Workshop with multiple emergency responders

After the extraction of the brainstorming session data from the Oslo workshop, seven categories were identified as requirements for COP map-based interfaces: (1) symbolization, (2) visualization, (3) extra information, (4) functionality, (5) standardization, (6) knowledge, and (7) management.

Among the participants, the symbolization issue (1) generally appeared as a requirement of a common cartographic symbolization and a standardized symbol usage with a common cartographic design of basic map backgrounds. The backgrounds should be established for all emergency responders, and desired information should be overlaid on those basic map backgrounds. Visualization (2) was identified as a map or a graphic, with responsibilities regarding map-based extra information (3). The latter should result in developing mapping solutions tailored to needs, i.e., it is necessary to have a map display with thematic layers and levels of info-types such as electricity, water, waste, weather, crimes, operations, activities, and statistics. These maps should serve as a foundation, and emergency responders need more situation-specific overlays, e.g., weather forecasts, power, resources. A complete resource overview across agencies and organizations should be included in the map. In turn, functionality (4) should contain a set of predefined interactive analytical functions, for instance, sharing the same COP map-based interface across different agencies at a national level to avoid misunderstandings caused by inconsistencies in terms of geographical names. A common interface should support transferring data or images, real-time sharing of resources and events. As some attendees argued, it is important to have a map-based interface for "drill-down" and to have "various perspectives" such as satellite-night-sea, sea level view, and aerial imagery. The stakeholders need more openness to connectivity as third-party actors, and the compatibility between different map systems. The map solution should be intuitive and made available as a unified system both internally and externally.

The participants reported on the need for establishing a "sharing regime" standard (5), i.e., a national-level standard for providing and sharing information. The standardization should include the datasets to be integrated in different systems. It is important to have a joint map repository for all Norwegian emergency map services. The leading agency should report to the collaborating agencies by following a standardized template with map overlays. The participants also expressed knowledge needs (6) regarding existing solutions and various sources that can be used on the map. As an example, one of the representatives from the police referred to the CompStat system developed in the 1990s at the New York Police Department to help reduce crime (Weisburd et al., 2003). CompStat stands for 'computer statistics' and supports law enforcement dealing specifically with crime. Lastly, the management aspect of the overall map-based interfaces (7) was mentioned to be equally important as good technologies. The map-based information of any kind should be a "fresh ware" that needs to be updated frequently, e.g., every week. However, this implies further challenges since adequate human resources are necessary to administrate and maintain such systems.

Meeting with the Norwegian Coastal Administration

In this meeting, a representative from NCA presented and gave a demonstration of the agency's COP map-based interface. During the meeting, five members of the research team were asking follow-up questions.

While NCA's main focus is marine traffic, its primary concern is oil spills resulting from vessel accidents. NCA's map-based solutions facilitate documentation, effective decision-making and action. The tool which is freely available at NCA's website does not offer typical COP functionality. However, such functionality is provided

through the tool's version "Kystinfo Beredskap" [eng: Coastal-information Emergency].

Kystinfo Beredskap has an open part that provides typical web mapping functionality, and another part that is password protected and assigns users specific roles. This part integrates background maps with thematic overlays such as environmental characteristics and infrastructure, with situation data such as real-time observations and engaged resources, as well as weather forecasts and driveway calculations. Moreover, Kystinfo Beredskap enables selective and targeted information sharing. The tool's recent developments have been comprehensively tested with emergency responders dealing with oil spills. The functionalities include accessing remote measurement data from boats, aircrafts, and drones. A lot of remote sensing data undergo real time geo-processing.

Interviews with COP software producers

Locus Public Safety

The first-response agencies, i.e., police, fire departments, and ambulance services are the target users of the -solutions offered by the Locus Public Safety company. The solutions consist of tools for command posts, such as TransFire for fire departments, TransMed for ambulance services, and Tellus for the police, as well as tools for emergency mobile units such as TransMobile. Both tool types communicate with each other, e.g., TransFire can continuously update task descriptions that are automatically provided to specific mobile units that use TransMobile. Furthermore, TransMed and TransFire offer customized map data, with functionality of map-based interfaces tailored to organizational responsibilities and the workflows of the respective agencies. The geographic and map-based components are "integrated from external mapping companies", according to customer specifications. The current generation of systems has not been integrated with other map-based solutions, but cross-organizational collaboration was said to be increasingly required to fulfill the responsibilities of each agency.

Tools that enable multi-agency data access and dynamic integration of real-time geographic content (e.g., resources, events, missions) across various agencies are not yet supported in the company's products. This was not due to technical restraints, but rather related to concerns about legal frameworks and systems requirements from customers. Some information has been already shared for specific users, e.g., emergency medical communication centers have an overview of police cars and fire trucks and, as the interviewee put it "I don't think the trend is to share less, I think the trend is to share more." It was emphasized that tool development is a multistage process with mutual interaction between user groups and system designers and, as the interviewee put it "it is very rare that something that is really good comes without a proper effort." Agencies often do not see the benefits of seeing extra information on their map displays, until they have such information provided. Then, they can determine new operational tasks.

As the interviewee suggested one solution could be to assign "a unique number to each emergency mission then you can start to link things together so that you can distribute in the car also so that they on the mission can gain position on others on the same mission." Thanks to this one can share the operational picture across the three first-response agencies based on such unique number. Having all information on a screen instead of reading various textual reports is an essential advantage. Moreover, various local actors expressed willingness to share information on maps, but one needs to remember that the actors also have sensitive data they are not allowed to share.

Symbolizing data in map-based interfaces was stated to be a challenge, as "too much data shown on the map means no information, but only data and noise." The company tries to follow design solutions already known from maps published by Norwegian authorities. Moreover, the company has also elaborated its own standardized symbol scheme, which is for instance implemented in TransMed. When it comes to background maps, the company has a map variant in which the amount of information is reduced if zoomed out. This helps emphasizing real time data content. The latter is typically visually encoded by means of symbols from the emergency symbols set from the Norwegian Spatial Data Infrastructure register[1]. Additionally, the symbols are color-coded depending on determined principles, e.g., in TransMed, the symbols are presented in red, yellow, green, and white, depending on the event priority. Several agencies use the same symbology; however, there are still needs for a common symbology, e.g., if a specific area is contaminated and first-response agencies need to know that they need protective clothing. Furthermore, the way the same information is presented in command posts and in the field differs. For example, in outdoor solutions colors are saturated and strong, thus one can read a map display with less details, when moving, in sunlight and from different view angles.

[1] https://register.geonorge.no/symbol/symbolpackages/details/a7c44707-7869-4edd-bea7-c7abb2437d05

Avinet

The company has so far delivered several map-based decision support tools for directorates, county governors, and county councils in Norway. Although Avinet develops map-based interfaces based on specific requests, the tool development process is typically stepwise and requires continues collaboration with the customer. As the interviewee put it "together we find a solution." This means that over a development process the functionality evolves based on specific needs that are reflected in offered interactive functions. Their map-based tools are used, for example, in exercises and, along with exercise customization, modification needs arise. Continuous modifications were needed, for example, during the development of map-based solutions for NCA.

Although Avinet has developed tools for various agencies, NCA is the main user of its map-based solutions for information sharing. In NCA, the need for map-based interfaces for emergency management and situation awareness has been recognized quite early. The main reason were some major ship accidents that resulted in, e.g., oil spills that had environmental consequences of diverse scale. Therefore, Avinet's solutions were needed to "register places where oil spills were detected and their aftermath in relation to what actions were required and what resources were available to help cope with the damages." In addition to NCA, there are many actors involved in this kind of scenario that needs common situation awareness, such as various inter-municipal committees for acute pollution. Such awareness requires access to information from various sources, e.g., information about boat traffic in connection with the incident, but also after the incident, to see what resources can be obtained. Information from third-parties are also needed, such as data on vulnerable or protected areas from the Norwegian Environment Directorate. Finally, the development process of map-based interfaces for emergency responders is challenging since it is not only about providing data and functionality to responsible agencies during an emergency preparedness situation. Such interfaces are also in use by third-party actors such as media to gather necessary information. As the interviewee put it, "Third-party actors (…) have the benefit of knowing what is going on with an oil spill that have moved on and so on. So that is an important part (…) to gather information there and then, but also to be able to spread it."

There are no specific repositories with standardized symbols in use by Avinet and it is the customer who decides how specific information should be represented on a map. However, Avinet needs to adapt such demands to map conditions. For example, the needs expressed by a customer may lead to problems with map interpretation since one "often needs to see a lot of information at the same time, and a lot of the data one may get from third-party sources." Then, "the third-party objects are represented with a certain color that the third-party has determined as required." However, the color cannot be used in an emergency or planning context that already employs this color to encode a specific message. As the interviewee put it "if you sew together many actors you will have a conflict." Therefore, a common symbol library will help to avoid misunderstandings.

DISCUSSION AND CONCLUSION

Emergency management in Norway follows some key concepts relating to decentralization and adaptability. Moreover, part of the COP map-based interfaces in use as of today have been primarily designed for planning and execution of day-to-day operations, with emergency response support being a secondary focus. This influences how emergency responders approach cross-organizational data sharing.

In Norway, there are several map-based emergency tool providers and the lack of system interoperability is visible. This issue is not caused by technical restraints, but rather, organizational and formal (RQ#2). The survey on existing COP tools is impeded by the fact that emergency tools undergo continuous improvements. Prototypes are often confidential and designers as well as stakeholders involved in the development process are not allowed to comment on this. The tools offered by Locus Public Services and Avinet differ in terms of form and provided functionality. While the latter company offers typical web mapping solutions that have been additionally equipped with COP functionalities (e.g., Kystinfo Beredskap), Locus primarily designs tools for first-response agencies that need comprehensive solutions for their command posts (e.g., TransFire) cooperating with their field teams that need simplified map displays (e.g., TransMobile). However, no matter the tool's origin, the companies' recent COP software undergoes improvements towards better use of map-based solutions within the whole system (RQ#2). Hence one might expect that the companies' products will gradually offer more extensive COP support.

The surveyed tools lack common solutions, i.e., they implement various system functionalities and symbology (RQ#1). This issue can be solved by the principle "different systems – same data", but further efforts are needed to standardize content and its graphic representation used by various systems. A COP map-based interface can constitute a collection of recognized operational pictures gathered from collaborating emergency responders. In the COP, the information is merged into a common geographical frame. Such a composite collection offers data fusion and correlation of recognized operational pictures containing elements from the perspectives of the collaborating emergency responders. As argued by Wang and Wen (2010), a standardized disaster map symbology and color-coding can be built up through a comprehensive investigation of different agencies involved in the

specific disaster management scenarios. In this way, different map readers can improve the interpretation of the same disaster map and ambiguity can be avoided. As McNeese et al. (2006) stated, the success of the COP depends on the support of user-centric affordances and visualizations designed according to the principles of situated cognition (Greeno and Moore, 1993). Referring to the companies' efforts to engage end-users in the development process, the role of the user-centric approach is visible and of growing importance.

This work-in-progress outlines some issues related to the development of COP map-based interfaces for emergency responders. In our further efforts, we intend to continue with translating these issues into a set of requirements, and next, processes that provide the capabilities needed to maintain a map-based COP across organizations.

ACKNOWLEDGMENTS

This research constitutes part of the INSITU project funded by The Research Council of Norway. We are grateful to the emergency management professionals contributing to our study.

REFERENCES

Adibhatla, V., Shapiro, A., McNeese, M. D. and Balakrishnan, B. (2009) Design and development of a Transactive memory system prototype for geocollaborative crisis management, *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 53, 4, 389-393.

Baber, C., Stanton, N. A., Atkinson, J., McMaster, R. and Houghton, R. J. (2013) Using social network analysis and agent-based modelling to explore information flow using common operational pictures for maritime search and rescue operations, *Ergonomics*, 56, 6, 889-905

Balakrishnan, B., Pfaff, M., McNeese, M. D. and Adibhatla, V. (2009) NeoCITIES Geo-tools: Assessing Impact of Perceptual Anchoring and Spatially Annotated Chat on Geo collaboration, *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 53, 4, 294-298.

Björkbom, M., Timonen, J., Yiğitler, H., Kaltiokallio, O., García, J. M. V., Myrsky, M. ... and Virrankoski, R. (2013) Localization services for online common operational picture and situation awareness, *IEEE Access*, 1, 742-757.

Chen, T., Su, G., and Yuan, H. (2014) Creating common operational pictures for disaster response with collaborative work, *WIT Transactions on Information and Communication Technologies*, 47, 393-400.

Chmielewski, M. and Gałka, A. (2009) Automated mapping JC3IEDM data in tactical symbology standards for Common Operational Picture services, *Proceedings of the Military Communications and Information Systems Conference MCC*.

Deschamps, A., Greenlee, D., Pultz, T. J. and Saper, R. (2002) Geospatial data integration for applications in flood prediction and management in the Red River Basin, *Geoscience and Remote Sensing Symposium, IGARSS '02*, IEEE International, 6, 3338-3340.

Dymon, U. J. (2003) An analysis of emergency map symbology, *International Journal of Emergency Management*, 1, 3, 227-237.

Endsley, M. R. (1995) Toward a theory of situation awareness in dynamic systems, *Human Factors, The Journal of the Human Factors and Ergonomics Society*, 37, 1, 32-64.

Gotz, D. and Zhou, M.X. (2009) Characterizing users' visual analytic activity for insight provenance, *Information Visualization*, 8, 1, 42-55.

Greeno, J. G. and Moore, J. L. (1993) Situativity and symbols: Response to Vera and Simon, *Cognitive Science*, 17, 1, 49-59.

Friedmannová, L. (2010) Designing map keys for crisis management on the regional operational and informational centre level: monitoring transport of dangerous goods via contextual visualization, *Geographic information and cartography for risk and crisis management*, 425-437, Springer, Berlin, Heidelberg.

Grottenberg, L. O. and Njå, O. (2017) Applying a systems safety approach to the development of GIS in the Norwegian emergency management domain, *Safety and reliability—theory and applications*, CRC Press.

Hager, R. S. (1997) *Current and future efforts to vary the level of detail for the common operational picture*, Naval Postgraduate School, Monterey, CA, USA.

King, D. (2005) Humanitarian knowledge management, *Proceedings of the 2nd International ISCRAM Conference*, Belgium: Brussels.

Kuvedžić Divjak, A. and Lapaine, M. (2014) The role of the map in a crisis management environment: applying the theory of cartographic communication and visualization, *Collegium antropologicum*, 38, 1, 187-193.

McNeese, M. D., Pfaff, M. S., Connors, E. S., Obieta, J. F., Terrell, I. S. and Friedenberg, M. A. (2006) Multiple vantage points of the common operational picture: Supporting international teamwork, *Proceedings of the 50th Annual Meeting Human Factors Ergonomics Society*, 467-471.

Munkvold, B. E., Radianti, J. R., Rød, J. K., Opach, T., Snaprud, M., Pilemalm, S. and Bunker, D. (2019) Sharing incident and threat information for common situational understanding, *Proceedings of the 16th International ISCRAM Conference*, Valencia, Spain.

Norwegian Ministry of Justice and Public Security (2016) Risk in a Safe and Secure Society, On Public Security, *Meld. St. 10 (2016-2017) Report to the Storting (white paper)*.

Opach, T. and Rød, J. K. (2014) Do choropleth maps linked with parallel coordinates facilitate an understanding of multivariate spatial characteristics?, *Cartography and Geographic Information Science*, 41, 5, 413-429.

Robinson, A. C., Roth, R. E. and MacEachren, A. M. (2010) Challenges for map symbol standardization in crisis management, *Proceedings of the 7th International ISCRAM Conference*, Seattle, USA.

Sikkerhetsutvalget (2016) Samhandling for sikkerhet, Beskyttelse av grunnleggende samfunnsfunksjoner i en omskiftelig tid, *Norges offentlige utredninger 2016: 19*.

Van Dijk, H. (2015) Situation Awareness in Crisis Situations: Development of a User Defined Operational Picture, *Proceedings of the 12th International ISCRAM Conference*, Kristiansand, Norway.

Wang, F., Wen, R. and Zhong, S. (2010) Key issues in mapping technologies for disaster management, *2nd International Conference on Information Engineering and Computer Science*, IEEE.

Wegner, D. M. (1987) Transactive memory: A contemporary analysis of the group mind, *Theories of group behavior*, 185-208, Springer, New York, NY.

Weisburd, D., Mastrofski, S. D., McNally, A. M., Greenspan, R. and Willis, J. J. (2003) Reforming to preserve: Compstat and strategic problem solving in American policing, *Criminology & Public Policy*, 2, 3, 421-456.

Zhou, M. X. and Feiner, S. K. (1998) Visual task characterization for automated visual discourse synthesis. *Human Factors in Computing Systems Conference*, 18–23 April 1998, Los Angeles, New York: ACM Press, 392-399.