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# SHARING INFORMATION FOR COMMON SITUATIONAL UNDERSTANDING IN EMERGENCY RESPONSE

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

Tomasz Opach  
*Norwegian University of Science and Technology, tomasz.opach@ntnu.no*

Sofie Pilemalm  
*Linköping University, sofie.pilemalm@liu.se*

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

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

*See next page for additional authors*

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**Authors**

Bjørn Erik Munkvold, Tomasz Opach, Sofie Pilemalm, Jaziar Radianti, Jan Ketil Rød, and Mikael Snaprud

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*Research in Progress*

Munkvold, Bjørn Erik, University of Agder, Norway, [bjorn.e.munkvold@uia.no](mailto:bjorn.e.munkvold@uia.no)

Opach, Tomasz, Norwegian University of Science and Technology, Norway,  
Linköping University, Sweden, [tomasz.opach@ntnu.no](mailto:tomasz.opach@ntnu.no)

Pilemalm, Sofie, Linköping University, Sweden, [sofie.pilemalm@liu.se](mailto:sofie.pilemalm@liu.se)

Radianti, Jaziar, University of Agder, Norway, [jaziar.radianti@uia.no](mailto:jaziar.radianti@uia.no)

Rød, Jan Ketil, Norwegian University of Science and Technology, Norway, [jan.rod@ntnu.no](mailto:jan.rod@ntnu.no)

Snaprud, Mikael, Tingtun AS, Norway, [mikael.snaprud@tingtun.no](mailto:mikael.snaprud@tingtun.no)

## Abstract

*Emergency responders lack support to effectively share information and establish a common operational picture (COP), for reaching shared situational understanding of threats and incidents. This challenge is multifaceted: lack of a systematic overview of information elements that are critical to share in different crisis scenarios; no common map interface in place using standard symbols; and different terminologies used across disciplines, resulting in possible communication and coordination problems.*

*The paper presents a research project initiated to provide a systematic approach for effective sharing, integration and use of information from different sources, to establish a COP and shared situational understanding among multiple actors in emergency response. The solution to be developed will provide a common map-based interface, integrating harmonisation of terminology and collaboration support for information sharing and synthesis. The enhanced COP will also support evaluation and learning from exercises and incidents. The project involves close collaboration with emergency management stakeholders in Norway, for requirements analysis, participatory design, and validation of project deliverables. The research will improve information sharing and decision support in emergency operations centres, which will contribute to improve societal resilience through more effective response capability.*

*Keywords: emergency management, common operational picture, situational awareness, geographic information systems, terminology harmonisation.*

## 1 Introduction

The public sector across the world is faced with increasing challenges in terms of natural disasters, increased socio-economic gaps, urbanisation with depopulation of rural areas, aging populations, migration streams, war and terrorism (e.g., Haddow et al., 2013). All of this affects crisis management in an emergency response sector which has often experienced substantial financial cutbacks and resource shortage. A direct consequence in many countries is increased collaboration among professional emergency response organisations, but also cross-sector collaborations bringing in new stakeholders, e.g. semi-professionals, non-profit organisations and volunteers (Pilemalm et al., 2016). Meanwhile, a recurring challenge in emergency response is to quickly be able to collect and integrate relevant information to form an initial shared understanding of a crisis situation, and to dynamically update a common operational picture (COP) of the evolving incident (Laakso and Palomäki, 2013). The core of this challenge is to be aware of the information requirements of the collaborating partners, effectively share relevant and timely information to the right receivers, and similarly - to know what information is available to be requested (Petrenj et al., 2012). However, evaluations from several incidents and large-scale exercises document challenges of ineffective information sharing between involved responders and lack of COP (e.g., Bunker et al., 2015; Steigenberger, 2016; Wolbers and Boersma, 2013).

While an increasing amount of digital information sources are available, the information landscape remains fragmented with lack of interfaces among the different sources and a varying data quality and data uncertainty. Digital map services provide a key resource for developing a COP. However, the lack of standardisation of tools and symbols in use for crisis maps limits the possibility for integrated use for sharing incident and threat information across collaborating entities (JRCC, 2018). Further, as highlighted by the Norwegian Ministry of Justice and Public Defense (Stm. 10, 2016-2017), different terminology in use by the different responders for depicting the same concepts and events also represents a challenge for information sharing and shared situational understanding. Finally, there is currently limited support for visualising and sharing a COP as a basis for systematic learning from incidents and exercises.

### 1.1 The INSITU project

To address the above-mentioned challenges, the Centre for Integrated Emergency Management (CIEM) at University of Agder, Norway, has initiated a project titled “Sharing Incident and Threat Information for Common Situational Understanding” (project acronym INSITU). Funded by the Research Council of Norway, the goal of this project is to contribute to effective sharing, integration and use of available information from different sources, to establish a COP as a basis for shared situational understanding. Reaching this goal requires:

- (a) systematic and comprehensive analysis of current practices and needs for information sharing,
- (b) supporting harmonisation of crisis terminology,
- (c) developing suggested standards for intuitive and explicit map symbols,
- (d) developing and designing a user-friendly and easy-to-use common map-based interface,
- (e) developing methods and tool support for collaborative information synthesis.

These research challenges are currently being addressed by an interdisciplinary team of experts in emergency management, information systems, geographic information science and systems (GIS), terminology harmonisation, and computer science. In addition to CIEM, the academic partners include the Norwegian University of Science and Technology (NTNU), Department of Geography, the Center for Advanced Research in Emergency Response (CARER) at Linköping University, Sweden, and the Interoperability in Extreme Events Research Group, The University of Sydney Business School. Further, two companies participate in the project consortium: Tingtun AS as a developer of methodology and software for terminology harmonisation, and One Voice AS as supplier of the leading crisis management system (CIM) in Norway. End user involvement is secured through the participation of the

emergency preparedness office of the County Governor in Agder as a project partner, and a reference group with broad representation of core emergency management stakeholders.

## **1.2 Research questions**

A core focus of the INSITU project is to strengthen the collaborative process in establishing a COP and shared situational understanding. This will include contributing to harmonisation and standardisation of crisis-related terminology and map support, and procedures for effective collection and sharing of relevant information. The project seeks to answer the following research questions:

- Which information elements are critical to share in scenarios involving collaboration between several emergency responders, and how and in what formats can this information be accessed?
- What are the perceived needs for harmonisation of terminology in use between the different responders, and how can such harmonisation be supported?
- How can geographic resources and interactive map-based interfaces be used more effectively to support collaboration and shared situational understanding, e.g., through standardisation of map symbols and intuitive functionality achieved through a user-centered design process?
- Which method and tool support is required for effective synthesis and presentation of information from different sources, as a basis for common situational understanding and for evaluation and learning from incidents?

Overall, for being able to improve collaborative practice in this domain, the project also needs to focus on the underlying sociotechnical factors influencing current practice for information sharing and tool use, and how this practice varies among different stakeholders. These factors can include organisational, political and cultural aspects, as well as legal and security concerns. The complexity of the problem will require building on several theoretical perspectives, including situational awareness and sensemaking, CSCW, distributed cognition, situated action, and information processing theory.

## **2 Background research and experience**

Former research has provided important contributions in the form of concepts, architectures and tools for supporting situational awareness and COP (e.g., Cordeiro et al., 2015; Galton and Worboys, 2011; Luukkala et al., 2017). Yet, experience from practice shows that developing a shared situational understanding remains challenging. For example, in a seminar hosted by the Norwegian National Forum for Exercises and Evaluation in 2018, Norwegian emergency responders discussed current challenges in establishing a COP and shared situational understanding. Among the barriers discussed were inefficient information sharing due to lack of knowledge on the information needs of the different response organisations, and problems with interoperability of existing support technologies being used by the different responders. The responders agreed that rather than aiming for developing a joint, national COP supporting different scenarios, what is needed is an information infrastructure supporting COPs for specific scenarios that can be adapted to the context of the local emergency responders. Further, several pointed to that a COP in itself does not guarantee shared situational understanding, as a COP could still be interpreted differently by the various sectors and disciplines involved in the operation.

The latter point is consistent with the discussion by Bunker et al. (2015) on how existing solutions for supporting a COP are not able to represent “the range of perspectives, options, facets and changes that often challenge responders” (p. 52). Further, there is currently no universally agreed upon definition of a COP. The International Forum to Advance First Responder Innovation (IFAFRI, 2018) also lists as one of four capability gaps the first responders’ ability to collect data from traditional (e.g., weather maps, sensor readings) and nontraditional (e.g., social media) information sources and integrate this data into a user-configurable COP.

This project focuses on three core elements in supporting a common situational understanding: 1) harmonisation of terminology; 2) integrated map services; and lastly 3) collaboration support for information sharing.

## 2.1 Harmonisation of terminology

The starting point of the efforts to support a common situational understanding is exact, concise and uniformed terminology. The open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction has issued a document covering terminology in 2016 (UN, 2016), and standardised terminology is reported to contribute to more precise disaster assessments (OCHA, 2018).

Unfortunately, the terminology needed to coordinate joint actions is not well established and not even harmonised among the first responders within one country. As an example of this challenge, there are at least four different Norwegian terms in use for an incident site (“åsted”, “fareområde”, “skadested”, “tiltaksområde”). In addition, we have sectorial abbreviations for locations related to an incident site, like the following used by the Police: “S” for “Samlested for skadde” meaning location to gather the injured, or “STY” for “Venteplass for hjelpestyrker” meaning waiting location for the support squad.

The choices of terminology will have many underlying reasons, including historical, cultural and political. As an illustration of this challenge we note that the work for developing a common terminology for the emergency management sector in Norway has been ongoing for more than a decade, with responsibility shifting among different government entities, and is still not completed (JRCC, 2018; Stm. 10, 2016-2017).

This problem is not specific for Norway. Snaprud et al. (2016) have explored the availability of crisis vocabularies in several countries and found that if such resources exist they are generally scattered on different websites, not available via Application Programming Interfaces (APIs), represented in different formats and forms, and not harmonised across sectors.

The following are examples of useful resources on process and methodology for terminology harmonisation that will serve as a basis for addressing this area in our project: Terminology work - Harmonisation of concepts and terms (ISO 860:2007), Unified terminology for society protection and preparedness (“Enhetlig terminologi för fackområdet samhällsskydd och beredskap”), Socialstyrelsen, Sweden, Difi guideline for concept coordination (“Standard for begrepskoordinering”), and Semicolon’s project guideline on harmonisation of concept and regulation between agencies (“Harmonisering av begreper og regelverk mellom etater”).

## 2.2 Integrated map services

As documented in the recently published Handbook for the Norwegian Rescue Services (JRCC, 2018), no common norm exists for map support among the different first responders and public emergency stakeholders. A range of different software platforms for map services is currently in use among emergency responders in Norway, with different user habits and routines. Examples of such platforms include ArcGIS, Avinet, Basecamp, GIS-link, Locus TransMed, Locus TransFire, Terra and Vision. However, interviews with emergency responders show that none of these services are considered to fully cover their needs. Furthermore, the use of symbols and colours is not fully standardised, and good drawing functionality is not fully incorporated. There are also local variations in the services utilised within each sector, and Grottenberg and Njå (2017) point to the decentralised nature of the Norwegian emergency management system as a barrier for implementation interorganisational GIS systems. These factors together limit the possibilities for effective information sharing based on a common map interface, and point to a need for more standardisation of map support that also allows for integrating data from different sources (JRCC, 2018; Wu et al., 2013).

While formalised map symbol standards for emergency contexts do exist, these have not been widely adopted by map providers (Robinson et al., 2013). A main goal for map displays is to provide exact, meaningful and effective representations of spatial information using graphical encoding (Tufte, 2001)

through visual variables (Bertin, 1967) executed in cartographic symbols. Ideally, all users should understand the symbols correctly, quickly, and identically, but this is not always the case. Further problems arise when map users are unable to spend time referring to a legend and encoding graphical symbols during the map reading process because the map is used in an emergency situation where response time is critical (Akella, 2009).

Although a change is needed to encourage the standardisation of symbols for emergency response and, as a result, to design a common library of map symbols, future maps for emergency management must be better adapted to individual user groups (Wu et al., 2013). As agencies are obligated to collaborate in their operational practice and emergency scenarios during crisis incidents such as industrial hazards or flooding, an extensive understanding of common scenarios and routines is required to equip a COP map display with adequate and efficient interactive functions. The functions, on the one hand, must efficiently support expert users in their operational tasks executed in various conditions and contexts, and, on the other hand, cannot make users confused with their multiplicity and complexity. Thus, our research will focus on map usability in both map content and visual controls to make map use more intuitive.

### **2.3 Collaboration support for common situational understanding**

Challenges of effectively sharing information across organisational boundaries for managing emergency situations have been documented in several studies (e.g., Laakso and Palomäki, 2013; Ley et al., 2014). An ethnographic study of disaster exercises in the Netherlands (Wolbers and Boersma, 2013) documents how the coordination process was distorted by the emergent management professionals attributing different meanings to information. They thus conclude that “information management during emergency response operations is about interpreting information and negotiating its relevance for different professions” (p. 195).

Existing procedures for situational reports provided by the Norwegian Directorate for Civil Protection specify the communication structures and actors involved. However, they do not provide detailed guidelines concerning what specific information elements to share, where to find them, and how to best synthesise and present this information. Research in the area of collaboration engineering focuses on how to develop detailed, easy to use ‘scripts’ for effectively conducting collaborative processes without a trained facilitator (de Vreede et al., 2009). These collaboration scripts also specify the use of relevant digital tools, and provide support for inter-disciplinary teams in effectively processing and making sense of available information (Lazareva and Munkvold, 2017). In developing such scripts, possible geographical distribution among the participants also need to be considered, to account for challenges of virtual collaboration (Bailey et al., 2012). Further, the level of prescribed action needs to be balanced against the need for flexibility in handling the uncertainty characterising an evolving crisis event (Schmidt, 1999). The theory of organisational information services (Mathiassen and Sørensen, 2008) can here be applied for classifying the information sharing services to be developed in this project, and the appropriate level of standardisation to avoid different forms of overload (structure, interaction, information and transaction overload).

Finally, there is currently also a lack of shared resources for supporting systematic learning from exercises. Being able to use a COP and an integrated map-based interface also in the evaluation phase, would represent a major improvement in practice. For example, Pilemalm et al. (2008) report how multimedia support tools for reconstruction and exploration of large scale exercises have the potential to provide a holistic view on the entire operation from multiple perspectives, thus enabling to also answer “why” events happened rather than just “what happened”.

## **3 Planned research approach**

The INSITU project will run from 2019-2022. In the following we briefly outline the planned research activities. As shown in Figure 1, the project will apply a combination of research methods for addressing the three focal areas in the project as presented in the previous section.

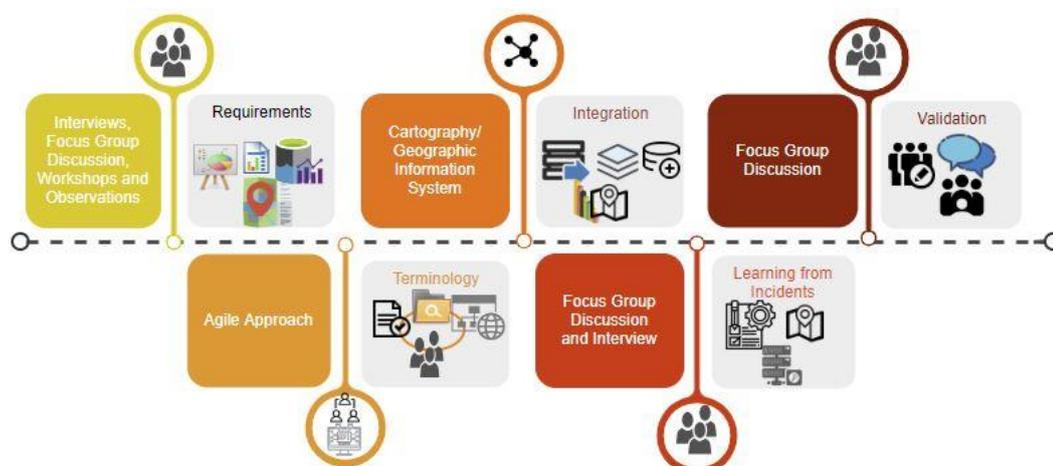


Figure 1. Combined research approach in the INSITU project

### 3.1 Requirements identification

The requirements identification phase will be conducted through literature review, document analysis, individual interviews and focus group discussion (FGD), workshops for requirements elicitation and prioritisation, and observation of emergency exercises. This task will focus on identifying the critical information elements needed to be shared between the involved stakeholders related to the different stages of the emergency, what information sources are currently being used, and the format of the relevant information. Implied in the requirements identification will also be a focus on the established practices for information sharing, and possible barriers for this as experienced by the different emergency stakeholders. This task will also scrutinize possible security concerns involved in sharing information between different responders, for example related to classified information at different levels. We will also consider how additional information sources that are not already used, such as sensor data and social media data, can provide useful input in the process of developing a COP.

In the requirements identification, we will explore different types of threats and incidents, as caused by both natural and man-made hazards, with the aim of identifying a set of core emergency scenarios that should be focused in the project. This will form the basis for design recommendations for a harmonised terminology and standardised visual encoding through map symbols and the integration of these in a common map-based interface. An agile approach will be used, working together with end users in a participatory design process (Pilemalm, 2018; Sanders et al., 2010), and collecting their feedback throughout the development process.

### 3.2 Terminology harmonisation

The practical harmonisation work will need to address different views across several organisational boundaries and legal and regulatory frameworks with their own institutional histories. As a starting point we suggest to build on experience and approaches from standardisation committees.

The methodology for harmonisation of terminology will combine a participatory process with a quantifiable justification process as a basis for selecting terms to be included in a common vocabulary. The idea is to compute a justification score for each term as input to the harmonisation discussions. The justifications will include references to external definitions of a concept in a law, regulation, standard, guideline, a recognised language dictionary or other prominent references. Properties for transmission of a term in a noisy environment, or the risk of misunderstanding a term for non-native speakers can

be additional aspects to consider for the practical use in joint actions. To determine such properties we plan to carry out user testing.

To enhance the methodology we will also seek to identify other valid reasons for adopting different terminologies as input to the discussions and explore how such reasons can be incorporated in the harmonisation process.

The sources of references and possible weights for them will be tested and agreed with the users in the participatory design process. The harmonisation will address both the form and the content of the terminologies. The form will cover how to represent the terminology from the metadata describing it, the terms and their properties including attributes and classifications.

To aid the harmonisation work we plan to prepare tool support to store the quantifiable justifications, their references and information about decisions taken. This can be important for possible later revisions.

We would also like to explore how the participatory process can scale up to cover larger groups and more diverse participants. We plan to gather experience from a smaller initial deployment to form a basis for ideas on how to scale up.

### **3.3 Map-based integration and collaboration support**

The aim is to integrate various interactive data and map displays into a single, consistent map-based interface facilitating shared situational understanding in the different phases of an incident. The resulting interactive tool support will provide users with a map display featuring switchable thematic layers showing standardised cartographic symbols representing critical information elements. The symbols will be retrieved from a shared data repository that is to be designed as a project deliverable. Of critical importance in this task is to avoid sharing irrelevant information that may lead to information overload. The map-based interface cannot be visually cluttered by a multiplicity of point, line, and area symbols, and at the same time, it cannot be overloaded by too many interactive functions. Therefore, the interactive tool support will be developed through a sequence of proof of concept implementations accompanied by rapid prototype assessments with target users, in order to test combinations of various map symbols with particular interactive functions.

Complementing the integrated map support for COPs, the project will develop collaborative scripts detailing information management procedures for collecting, sharing and synthesising information from different sources. These collaborative scripts will specify required information elements, the sources for these elements and how to access them, the procedure for sharing information with other stakeholders (including formats and tools), and how to effectively combine the information elements to support situational understanding. The collaborative scripts will be presented through an interactive, easy-to-use, web interface.

### **3.4 Supporting learning from incidents**

For developing enhanced support for systematic learning from incidents, a combination of focus group discussions, review of incident report studies, and After Action Reviews will be conducted. This task will address the need for common information sources supporting systematic learning from exercises and incidents. The integrated terminology, map and collaboration support will be adapted for this purpose. In addition, the possibility of adding functionality for recording and playing back event handling in the common map interface will be analysed.

### **3.5 Validation of project results**

The process for validation of project deliverables will be conducted iteratively throughout the project, using process walk-throughs for all project outcomes in workshops, questionnaires, field trial in relevant exercises, and validation in a simulated, realistic environment provided by CIEM in the form of an experimental operations centre facility for crisis management training and tool testing (CIEMlab).

## 4 Conclusion

The goal of the INSITU project presented in this paper is to contribute to strengthen the overall resilience of society by providing methods and tool support for developing common situational understanding among different emergency management sectors and units. The research will address critical shortcomings in today's practice, regarding harmonisation of terminologies in use and interoperability and standardisation of map resources. By this, the project will contribute to improved preparedness, response and learning from experience. Through broad involvement of key emergency management stakeholders in Norway, the project will facilitate knowledge development on practices in the different sectors and increased understanding of the information needs for the tasks and roles involved. The software tools developed and adapted in the project will provide easy access to a harmonised terminology and common map support, for being included in COPs, training material and procedures for inter-sectoral communication and collaboration.

Acknowledging the need for an interdisciplinary perspective when designing information systems support for cross-sector collaboration (Pilemalm et al., 2016), the INSITU project builds on knowledge from multiple, related research areas including situational awareness and COP, collaboration engineering, terminology management, GIS and crisis mapping, human-information interaction, user-centred design and policy science. The project will also contribute new knowledge in these domains, through combining harmonised terminology, standardised map support and collaboration scripts for information sharing and synthesis, in an integrated solution for enhanced situational understanding. Successful implementation of this solution will also require attention to the organisational, policy and regulatory aspects framing practice among the different emergency responders today.

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