Towards a Co-Created Emergency Management Collaboration Repository

Kristine Steen-Tveit
Centre for Integrated Emergency Management, University of Agder, Norway
kristine.steen-tveit@uia.no

Mikael Holmesland Snaprud
Tingtun AS, Norway
mikael.snaprud@tingtun.no

Jan Egil Heinecke
University of Agder, Norway
jan.e.heinecke@uia.no

Nora Fure
University of Agder, Norway
Nora.fure@tingtun.no

ABSTRACT

The need for information systems (ISs) to aid emergency management (EM) has been well established. Yet, despite the acknowledged benefits of ISs for EM, the support of ISs in the preparedness phase is weak. Complex EM operations require coordinated efforts across emergency organizations, which are facing enormous challenges related to the method of collaboration to cope with the impact. This paper presents an ongoing project initiated to develop an emergency management collaboration repository for a range of emergency responders, focusing on emergency cross-organizational collaboration, information sharing, exercises, and evaluations. A participatory design approach was applied for the system requirements elicitation and was carried out in two workshops with several EM stakeholders.

KEYWORDS

Collaboration support, information systems, training, preparedness phase, participatory design

INTRODUCTION

Emergencies force governmental organizations, non-governmental organizations (NGOs), and private organizations to prepare strategies that are suitable for managing emergency events, such as terrorism and the consequences of climate change (e.g., Burkle et al., 2012). The preparedness phase of emergency management (EM) is vital in determining its success and making the response more effective (Kusumastuti et al., 2021). No major emergency is ever tackled by a single organization. Rather, it requires a network of several emergency management organizations (EMOs) that cut across disciplinary, jurisdictional, and public–private sector boundaries (Kapucu et al., 2010). Collaboration among EMOs is challenging because it involves heterogeneous information needs, processes or structures, goals, resources, means of interacting with technology, confidential information, and other features within the organizations (Bharosa et al., 2010). This poses challenges for different EMOs, and the typical problems include mismatched goals, non-corresponding procedures, information overload, ignorance or the inability to determine which information needs to be shared, and time pressure. Further, it is difficult to understand each other's concepts (Carlström et al., 2019), such as hierarchy levels, action logic, and agendas (Berlin and Carlström, 2008; Snaprud et al., 2016). Overall, coordination during an emergency response is a challenging task, and the complexity increases along with the number of EMOs involved.

The mobilization of the involved EMOs to work together and prepare for disasters is important for identifying effective counter-disaster strategies (Balcik et al., 2010). When an emergency strikes, the involved EMOs are often placed in a constant state of reaction, not allowing them to examine their own or other organizations' systems and strategically plan further steps over time (Besiou et al., 2011; Oloruntoba et al., 2018). To reduce this effect, EMOs need to better comprehend their roles and integrate each stage of EM, which requires an accurate overview and understanding of relevant interrelated systems, procedures, and information needs among collaborating organizations (Oloruntoba et al., 2018). They are, after all, important elements of successful

collaboration and the development of a common situational understanding. In essence, developing a common situational understanding is a process that requires insight and knowledge sharing between the actors involved both before and during a crisis, where both the common and individual information needs, preconditions, strategies, and procedures must be structured and implemented as a process using IS support in different organizations (Steen-Tveit et al., 2020).

Over the past two decades, the practices of crisis preparedness, response, and recovery have become increasingly dependent on information and communication technology (ICT) to perform tasks (Soden and Palen, 2018). Evidence indicates that ICT is useful in each phase of crisis management, as it, for example, offers learning opportunities in the preparedness phase (Asadzadeh et al., 2020). Moreover, EM preparedness is a participatory management process in which all participating EMOs are expected to share knowledge (Matsuda and Okada, 2006). To make information as accessible as possible, it is important to take into consideration that the design of ISs is usable by all stakeholders without the need for adaptation or specialized designs for different users (Gjøsæter et al., 2021). This requires a focus on universal design in order to avoid accessibility issues and environmental barriers that can cause cognitive, physical, or visual impairments (Gjøsæter et al., 2020). These barriers can hinder cross-organizational collaboration and information sharing. In addition, universal design is needed to meet the requirements of the European Web Accessibility Directive (WAD) (Uutilsynet.no).

Many studies have focused on the method of developing and using different information systems (ISs) to assist stakeholders during the response phase of emergencies (e.g., Radianti et al., 2021; Rossel et al., 2016; Valecha, 2019). However, the preparedness phase is an important stage for different EMOs, as it helps them learn about mutual and organization-specific perspectives before the response phase. Additionally, previous research has presented the different organization-specific perspectives held by the responders on their roles'—for example, firefighters often see themselves as suppressors and, thus, operate from this narrow standpoint (Oloruntoba et al., 2018). In fact, to develop a common situational understanding, there is a need for the involved organizations to capture all perspectives of subjects, such as activities, goals, and systems, representing the emergency response phase in different scenarios. This will enable the involved organizations to know what is expected from them in their collaboration with other organizations, to provide them with relevant insights into what resources the collaborative organizations hold, and to understand others' action patterns. This will support the information-sharing processes that aid stakeholders in making the right decisions during the emergency response phase and, thus, providing a quicker response that is dependent on team-based collective actions (Endsley et al., 2003).

The purpose of this paper is to identify the requirements for an IS that can provide relevant knowledge repositories to different EMOs for the preparedness phase based on previous research, empirical data, and information based on past emergency experiences. Despite the acknowledged benefits of ISs for EM (EMIS), the ecosystem of EMIS remains fragmented, and the solutions are characterized by varying functionalities, interoperability, and focus points (Neville et al., 2018). To address the gap between research and practice, this study adopts a co-creation approach to establish knowledge and to create a prototype for an emergency management collaboration repository (EMCR). Further, participatory design has been chosen to elicit requirements from stakeholders before and during the design process (Radianti et al., 2018).

AIM OF THE STUDY

This study aims to present requirements for an IS that facilitate effective cross-organizational communication for preparedness and further function as a basis for multi-organizational exercises. We conducted two workshops to investigate and define barriers to collaboration among different support organizations; we will, thus, also discuss the study outcomes in terms of recommendations for the long-term improvement of EM preparedness.

In addition, the presented IS concept focuses on emergency cross-organizational collaboration and information sharing. The intended audiences are both researchers and practitioners in the crisis management domain. Therefore, the proposed IS approach needs to be further developed by both researchers and practitioners.

The focus of the study is EM exercises and preparedness forums, since stakeholders are under time pressure during the emergency response. However, the IS concept may not be limited to the preparedness phase and could apply to the response and recovery phases; it may also serve as a tool for evaluation after exercises and real events.

The remainder of this paper is structured as follows: We first explain the background and context of our work. We then describe our research method, which is followed by an overview of the results. At the conclusion, we discuss our findings and propose the steps ahead.

BACKGROUND AND STUDY CONTEXT

In this section, we first offer a general overview of state-of-the-art research concerning multi-organizational EM and the importance of shared mental models. We then present the study context.

Multi-organizational emergency management

EMOs face huge challenges related to their methods of collaboration and coordination that can be used to cope with the devastating impact of emergencies (i.e., those requiring a response going beyond the mandate or capacity of any single agency) (Greenwood et al., 2017). The response phase has a high degree of dynamism and uncertainty (Santos et al., 2008). The most important characteristics for assessing the impact of an emergency are the onset speed and the availability of perceptual cues (such as wind, rain, or ground movement in a forest fire). These factors affect EMOs in their preparation, completion of emergency response actions, and determination of the extent of casualties and degree of damage done to the environment (Lindell and Prater, 2003). Further, important cues must be shared and understood by all involved EMOs. Successful information sharing creates more common ground, which further leads to improvements in team performance (McNeese et al., 2006).

Complex emergencies require extraordinary efforts from EMOs and cannot be handled through ordinary routines and structures. Emergency operations that involve multiple stakeholders are often cause for inadequate information sharing (Waterman et al., 2021) and decision-making problems (Wang et al., 2020). There are developed principles for guiding the collection, review, dispensation, and use of information processes to support collaboration and decision-making; however, research has shown this is extremely challenging in ongoing emergency situations (Van de Walle and Comes, 2015). For this reason, there is a need to focus on the specific knowledge of each other's organizations, such as concrete elements that facilitate information sharing in multi-organizational EM (Waring et al., 2018). This should ideally be done *before* an emergency occurs by facilitating multi-organizational exercises and training scenarios (Steen-Tveit, 2020). Exercises can be highly cost and time intensive; however, several studies have demonstrated that it is possible to instill teamwork-related knowledge, skills, and attitudes using cost-effective alternatives (Morey et al., 2002). Training to promptly share critical information with the right stakeholders at the right time within EMOs is key to executing collaborative response activities. A suitable IS has the potential for more cost-effective training. Hence, there is a need for a cross-organizational IS that facilitates knowledge creation on relevant information, supporting stakeholders' understanding of the collaborating EMOs and their relation to the chain of management.

From a multi-organizational perspective, learning must focus on common improvements that can be emulated during future crises. Pilemalm et al. (2014) highlight that learning processes resulting in the modification of organizational goals or decision-making rules leading to certain actions (i.e., double-loop learning; Argyris and Schön, 1978) in EM are difficult to develop, since the proposed changes are often not accompanied by adequate organizational processes. To achieve such multi-organizational learning, there is a need for coordination among relevant EMOs. In addition, a common, dynamic, and up-to-date IS may solve some of the issues related to organizational processes. Many EMOs seem to be optimized and agile much more for internal efficiency than for the agility of multi-organizational collaboration and information sharing.

Importance of shared mental models

Mental models enable stakeholders to explain and predict their surroundings (Rouse and Morris, 1986), since they are frameworks or pattern-matching mechanisms that individuals carry in their minds. Several studies have analyzed pattern-matching mechanisms that connect the information stored in their long-term memory with a quick understanding of a certain context (e.g., Chen et al., 2010). Based on their training, education, and experience, stakeholders can develop mental models and recognize and link critical cues; they can further form an understanding of what certain separate information elements mean. While an individual mental model is a cognitive display of the structures forming the basis of interaction (Resick et al., 2010) and somewhat explains an individual's decision-making, a shared mental model represents the joint comprehension of all individuals involved in a team regarding concerns such as task, performance, and interaction (Cannon-Bowers and Salas, 2001). Stakeholders with developed shared mental models can often anticipate other team members' needs and proactively help them perform their tasks (Yen et al., 2006), which are important elements for effective teamwork.

STUDY CONTEXT

The study builds on findings from a recent research project (Munkvold et al., 2019). The results of this project support experiences of large emergencies (e.g., the Gjerdrum landslide in Norway in 2020 [Joint Rescue Coordination Centre, 2021], the 9/11 terrorist attacks in the United States in 2001 [Dearstyne, 2007], the

Norway massacre on 22 July 2011 [Gjørv, 2012], and Hurricane Katrina in 2005 [Boin et al., 2019]) in which the lack of relevant, cross-organizational information sharing resulted in an insufficient common situational understanding. Further, the results indicate that in the process of establishing a common situational understanding among different EMOs, insights into each other's concepts, such as hierarchy levels, action logics, and agendas, are crucial (Steen-Tveit, 2022). While there is a significant amount of research on the collaboration processes followed in multi-organizational EM, most ISs used in EM only facilitate information sharing and not the collaboration process or subsequent evaluation. In trying to bridge this research–practice gap, our study includes those that produce the knowledge and those that use it in EMOs: researchers and stakeholders, respectively (Table 1).

Table 1: Examples of key actors and support organizations in emergency management

Government	Private sector	NGOs
Ambulance services	Energy companies	Red Cross
Armed forces	Hotels, motels, and accommodation centers	Search and rescue dogs
Civil defense	Suppliers and vendors	The Salvation Army
Fire and rescue services	Warehouse operators	
Police services	Transport services	
Public hospitals		
Municipalities		
County governor		
Directorates		

METHODS

To improve EMOs' collaborative capabilities, this participatory design research was chosen to address the potential research–practice gap, which presumes close cooperation with stakeholders. Essentially, a participatory design approach should be adopted and developed for the ISs of EM in order to ensure that the needs of diverse stakeholders are taken into consideration (Gjøsæter et al., 2021).

This study builds on findings from the INSITU project (Munkvold et al, 2019) and follows the identified need for EMOs to have greater knowledge about each other and further develop shared mental models. We conducted two workshops with stakeholders working in supportive EMOs (i.e., they were not the first responders). The stakeholders from first-responder organizations have everyday experiences with handling emergencies, while supportive EMOs have a professional focus on other tasks and handle emergencies only when the event hits them and requires their response. We, therefore, chose to start by focusing on supportive EMOs in one county to gain a better understanding of their needs, perspectives, and field problems as a knowledge-creation opportunity.

Empirical Data Collection

Two workshops were conducted with the selected emergency responders (Table 2). The first was physical and lasted two hours, while the second was digital and lasted one hour. A document with a brief introduction to the purpose of the meeting was sent to brief the participants before the workshops, and at the conclusion, a document showing and explaining the results was sent to the participants using their professional e-mail addresses for validation and for any final remarks.

In the first workshop, the agenda included background information on the INSITU project (Munkvold et al., 2019). Then, the participants were requested to share their views and perspectives on the inhibitors and promoters of effective collaboration in writing. Subsequently, the listed perspectives were presented collectively and further revised in a PowerPoint presentation together with all the participants. The discussion resulted in some text adjustments and the categorization and re-categorization of the different inhibitors indicated earlier. The same method was used to identify the promoters of effective collaboration.

Table 2: Participants in the two workshops

Organization	Role	Workshop nr participation
County governor's office	Head of preparedness	1 and 2
Energy distribution company	Preparedness Coordinator	1 and 2
County	Preparedness Coordinator	2
Municipality	Head of preparedness	1 and 2
University	Head of preparedness	1 and 2

ANALYSIS

We applied thematic analysis (Bowen, 2009) to the study, which is a good approach to research; through it, researchers try to glean participants' views, opinions, knowledge, experiences, or values from a set of qualitative data. In this study, we aim to understand stakeholders' ideas and opinions about inhibitors and promoters related to the collaboration processes as well as the requirements that are important for an IS aiming to facilitate learning and the development of shared mental models.

The thematic analysis allows flexibility in interpreting the data, and in this study, we sorted the data into themes using an inductive approach. After receiving a thorough overview of the data, we labeled the data by descriptions of the content and identified relations among them. These categories were validated by the stakeholders during the second workshop. Finally, we arrived at a representation with the main themes: *inhibitors* and *promoters* of collaboration; each of these has several sub-categories presented in the next chapter (Table 3).

RESULTS AND DISCUSSION

The stakeholders who participated in the two workshops provided us with insights and different perspectives on the collaboration processes involving several EMOs during complex EM. The results show that there is a striking consensus among the participants that collaboration and practices need improvement. Several real examples of collaboration that did not work well were introduced and discussed in the workshops.

Table 3: Inhibitors and promoters of effective collaboration

Nr.	Inhibitors of effective collaboration	Nr.	Promoters of effective collaboration
I-1	Low motivation and limited understanding of their own role (in both individuals and organizations)	P-1	Thorough and complementary scenario-based descriptions of and protocols for responsibilities and multi-organizational collaboration
I-2	Unclear guidelines or protocols from the professional directorate(s) or authorities	P-2	Exercises involving multiple organizations
I-3	Limited knowledge of each other (e.g., tasks, responsibilities, contact information, and the IS used)	P-3	Clear protocols for collaboration evaluation and the use of results and the culture of cross-sectional result sharing
I-4	Different technologies and ISs	P-4	Access to technology and the IS for common operational picture and information sharing
I-5	Regulations preventing information sharing	P-5	Clear protocols for what information is to be shared, with whom, and how and the provision of use cases with examples linked to the regulations

I-6	Ineffective exercises and evaluations	P-6	Access to previous evaluation reports
I-7	Insufficient resources for building competence and systems for collaboration	P-7	Retention of the same understanding of the terminology and symbols
I-8	Different terminology	P-8	Access to a common harmonized terminology

The principles for guiding the collection, review, dispensation, and use of information processes to support collaboration are proven to be challenging in ongoing disaster situations (Van de Walle and Comes, 2015). This research aims to address the identified need to focus on the specific knowledge of each other's organizations, such as specific elements that facilitate information sharing in multi-organizational EM (Waring et al., 2018), which ideally must be carried out before an emergency occurs by facilitating multi-organizational learning arenas and training scenarios (Steen-Tveit, 2020). The results of this study provided the identification of several examples from practice, showing which factors inhibit and which promote collaboration among EMOs (Table 3).

Inhibitors of effective collaboration

Inhibitor I-1, "low motivation and limited understanding of their own role (in both individuals and organizations)," concerns the stakeholders' views on collaboration and information sharing, such as the importance of sharing information with other EMOs when information sharing does not necessarily benefit them. The informants state that the weak culture of information sharing is a possible explanation for this, as stakeholders do not regard other EMOs' perspectives and responsibilities as being as important as their own. This is not an uncommon phenomenon, as stakeholders in different organizations tend to emphasize their own professional standpoints (Imoussaten et al., 2014) and justify their own activities (Ditlev-Simonsen and Wenstøp, 2013). At the same time, this might be the reason for their limited understanding of their own role, because the roles within organizations change if they are internal or depending on whether they are in collaboration with other organizations. For example, a preparedness coordinator in a municipality will be responsible for following internal procedures, while in a multi-organizational operation, the same person is expected to function as a representative of the municipality in unfamiliar scenarios.

Inhibitor I-2, "unclear guidelines or protocols from the professional directorate(s)," is a factor that includes protocols for the use of a common available IS, guidelines for symbols and terminology, and information flows from the authorities. An example provided by one of the participants was the information shared during the COVID-19 pandemic, in which the directorate communicated with the county governor's offices and not with the municipalities directly. Inhibitors I-5, "regulations preventing information sharing," and I-7, "insufficient resources for building competence and systems for collaboration," are also presented as limitations affecting collaboration, which are caused partly by these three issues: legal limitations to sharing information among organizations, limited focus from professional directorates, and the existence of many issues within various organizations' responsibilities, prioritizing which may be considered more important than collaborating with external organizations. Inhibitors I-3, "limited knowledge of each other," and I-8, "different terminology," can be consequences of I-2, I-5, and I-7.

Inhibitor I-6, "ineffective exercises and evaluations," is a commonly found issue in multi-organizational emergency operations and exercises (e.g., Berlin and Carlstrøm, 2008). Some issues are related to the difficulty of understanding each other's capabilities, limitations, actions, logic, agendas, legislation, and hierarchical levels (e.g., Lee et al., 2009; Perry et al., 200 and of learning from similar events in other organizations (Crichton et al., 2009). The inhibitor can, thus, be considered a consequence of I-2, I-5, and I-7 and further a reason for I-3 and I-8.

Promoters of effective collaboration

Promoters P-1, "thorough and complementary scenario-based descriptions of and protocols for responsibilities and multi-organizational collaboration," P-3, "clear protocols for collaboration evaluation and the use of results and the culture of cross-sectional result sharing," and P-5, "clear protocols for what information is to be shared, with whom, and how and the provision of use cases with examples linked to the regulations," require EMOs to work together and develop joint strategies concerning protocols, scenarios, and evaluation criteria. Several studies put forth collaboration as an important principle for emergency planning (e.g., Alexander, 2005; Perry and Lindell, 2003). As a result of this planning, well-developed shared mental models and a culture of

information sharing may also improve because of the enhanced knowledge of their role in a multi-organizational emergency operation and further increased knowledge of the other EMOs. Promoter P-7, "possessing the same understanding of the terminology and symbols," is also likely to benefit from P-1, P-3, and P-5.

The use of ISs in the preparedness phase of EM includes the activities undertaken before an emergency strikes and aims to enhance the readiness of EMOs to respond to it (Reddick, 2011). Promoter P-4, "access to technology and the IS for common operational picture and information sharing," includes all the IS and ICT tools for the preparedness phase and must enable learning from a multi-organizational perspective with a focus on common improvements. Hence, Promoter P-2, "exercises involving multiple organizations," is a crucial element that can enhance the EMOs' readiness from a multi-organizational perspective. Thus, the emergency planning process should include P-4—namely, an IS for information sharing, exercises, and double-loop learning. Promoter P-6, "access to previous evaluation reports," belongs to P-4, as it should be included in the IS.

Requirements for an emergency management collaboration repository

The categories of the inhibitors of effective collaboration (I-1 to I-8) and those of the promoters of effective collaboration (P-1 to P-7) are connected, as several categories of promoters are solutions for several categories of inhibitors (Figure 1). This connection among the various categories invites a discussion of the requirements of the EMCR.

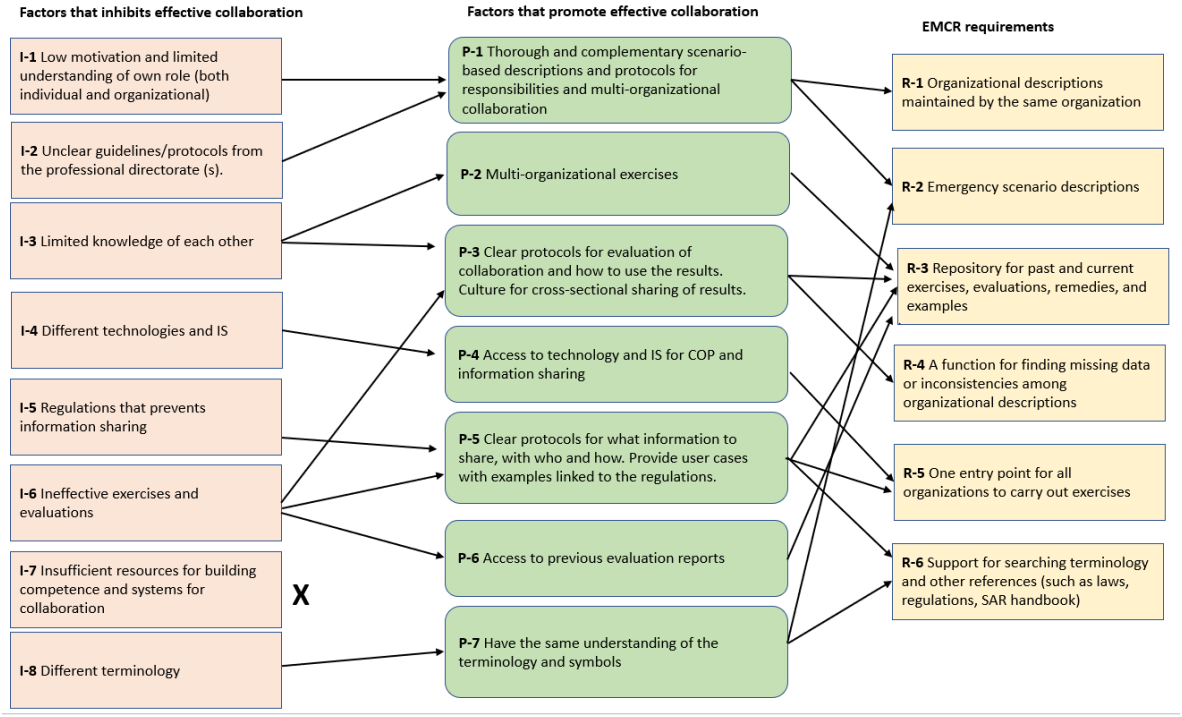

Figure 1: Connections between inhibitors, promoters, and EMCR requirements. The connections between the inhibitor and promoter can be perceived as a link from a problem to a possible solution. Further, the links between the promoters and EMCR requirements similarly point to the ways in which we propose solutions that can be implemented. The X indicates that we do not expect our approach to add new resources.

I-1 concerns stakeholders' low motivation to share information with other EMOs and limited understanding of their own role in multi-organizational emergency operations, which can be a result of unclear guidelines (I-2). These issues can only be solved by raising awareness about the collaboration needed to handle large events and by allowing increased access to this knowledge (P-1) through updated descriptions of the different EMOs and various emergency scenarios (R-1 and R-2). Multi-organizational exercises and clear protocols for how to evaluate and implement the findings (P-2 and P-3) can be implemented in the EMCR by providing a repository for exercises and evaluations and by detecting missing data and inconsistencies (R-3 and R-4). This will further increase the EMOs' knowledge of each other (I-3) and help them develop shared mental models.

A major problem for collaboration in EM is that the stakeholders have limited access to the same IS in both the preparedness and response phases (I-4) (Steen-Tveit and Munkvold, 2021). Having access to a common IS for

preparedness (P-4) will allow the stakeholders access to the same information (R-5), and they will hence be able to develop a common operational picture. Having EMCR requirements to provide all stakeholders with a common entry point for all accessible information can help the EMOs carry out effective exercises. Moreover, insufficient resources for exercises and building competencies (I-7) are a problem caused by insufficient government grants. However, several studies have demonstrated that it is possible to instill teamwork-related knowledge, skills, and attitudes using cost-effective alternatives (Morey et al., 2002), such as the proposed EMCR.

Table 4 summarizes which inhibitor is connected to the promoters and the EMCR requirement. These connections between the inhibitors and promoters can be—if not perfectly solved—aided by the EMCR requirements.

Table 4: Summary of inhibitors, promoters, and EMCR requirements

Inhibitors	Promoters	EMCR requirements	Comments
I-1	P-1	R-1 and R-2	A limited understanding is enhanced by scenario-based descriptions.
I-2	P-1	R-1 and R-2	Unclear guidelines are replaced by updated and clear guidelines.
I-3	P-2 and P-2	R-3	Limited knowledge is enhanced by descriptions and updated protocols.
I-4	P-4	R-5	One common IS is an entry point for the preparedness phase, and exercises can aid the understanding of the fragmented use of IS in the response phase.
I-5	P-5	R-5 and R-6	Regulations preventing the sharing of secure information must be better understood by providing easy access to various regulations and user cases.
I-6	P-3, P-5, and P-6	R-2, R-3, R-4, R-5, and R-6	Exercises and evaluations are supported by clear protocols, use cases, and access to previous evaluations.
I-7			This inhibitor must be solved by political regulations or higher grants; however, the EMCR can be a cost-effective alternative.
I-8	P-7	R-2 and R-6	A different use of terminology and symbols are solved by a common repository and a tool for searching terms and regulations.

Figure 2 presents the first stage of the EMCR design process based on this study's findings. The figure may be hard to read, as the text is in Norwegian and in a small font. Please note that the figure is only included to illustrate the main components of the EMCR. This design is outlined to be simple and easy to understand and use to support intuitive interaction and enable the user to focus on the information rather than the page design. This first design covers some of the main requirements derived from the workshops and discussions. The basic login form (A) is needed to protect private or sensitive information and to associate the correct organization with the user. A later iteration could allow the user to log in with a username and an exercise name so that they can preselect the emergency scenario and access links to the exercise documentation. Further revision of this form can also provide some general information about the EMCR. Once the user is logged in, the home screen (B) is shown with information about their organization for collaboration in the emergency response. Here, the user can also maintain or update this information if they are authorized to do so. A tab selection option is then presented so that they can select one of the emergency scenario themes. The top-level bar provides a search field for the user to quickly find relevant information from related national documents, such as a rescue handbook, and from the content produced by the regional stakeholders. The "Termer" button can be used to look up the meaning of terms directly from a document. A screen example for a forest-fire scenario is shown in scenario screen (C) with information about the scenario, an image, and a potential link to a video that provides examples and information about its management. Finally, D shows the menu so that the user can make a selection among scenario themes.

Among the parts not yet covered are a searchable FAQ list, search results pages, the rescue document hierarchy, and a form to gather points on the information an organization expects to obtain from others in a given scenario.

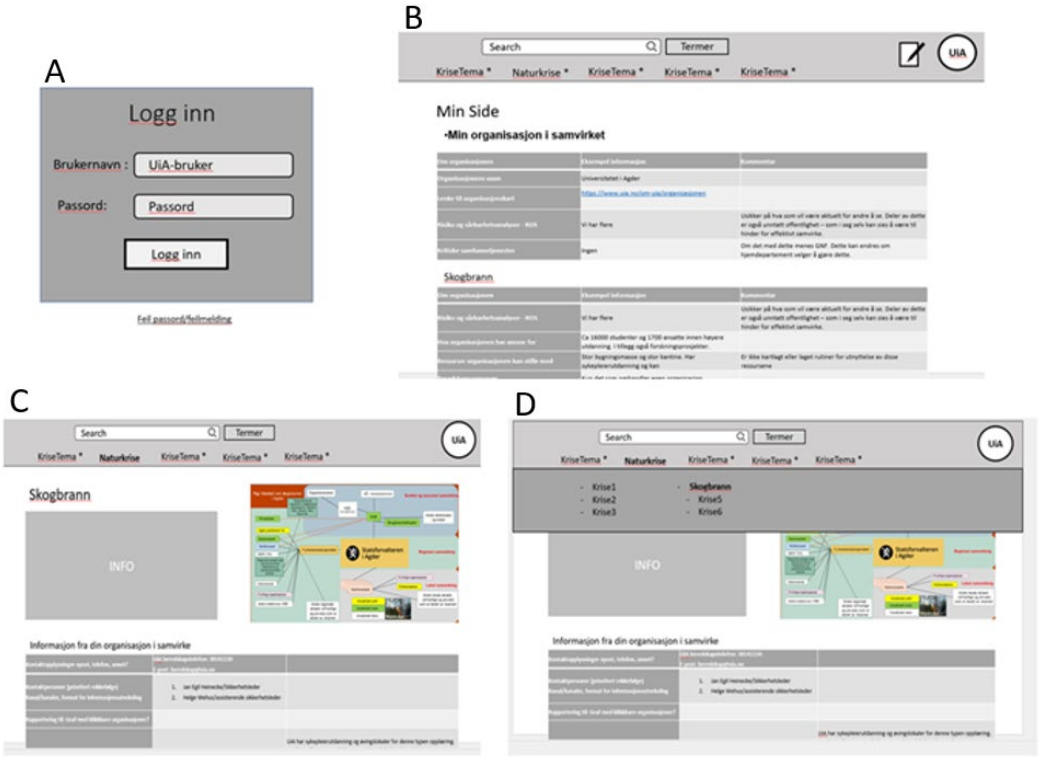

Figure 2: First stage of the EMCR design process

The user interface is designed to be accessible to all. During the development stage, we will try to consider how we can represent non-textual elements and test them with an automated checker tool to offer aspects such as sufficient color contrasts, ease of navigation, and labeling of the interaction elements. We will also conduct tests with a screen reader and expert testers.

To further improve accessibility, we will invite users with disabilities to carry out testing according to scenarios using their devices and assistive technologies.

To lower the threshold for users to report any remaining accessibility issues, we will also include a feedback mechanism available on all EMCR web pages. This feedback function is designed to meet the requirements of the WAD and has already been successfully tested with users from the Norwegian association for the blind. The same feedback mechanism can be used for wider user involvement (e.g., to collect their comments when using other online tools during an exercise or to collect them in the national rescue handbook).

CONCLUSION AND FURTHER RESEARCH

The research presented in this paper, followed by further investigation, will contribute to strengthening the collaboration between EMOs and developing knowledge that addresses the challenges presented in the previous sections. The proposed EMCR under development aims to provide an interactive, usable, and accessible platform with a knowledge repository for collaboration support for information sharing and synthesis, exercise planning, support evaluation, and learning. The design process will have a universal design focus, so that the stakeholders can contribute equally without barriers (Bennett et al., 2017). Further, the EMCR aims to be a helpful tool for developing emergency plans.

The research project will also provide a good opportunity for EMO stakeholders to discuss common information requirements in different scenarios, which may also result in an enhanced information-sharing culture. It is in

the process of establishing a connection to the national study program in preparation for the police academy. Such a collaboration will facilitate knowledge development in practice and increase the understanding of the requirements an EMCR must include.

The project involves close collaboration with EM stakeholders in Norway. In the next phase, the current number of participants will be increased to include stakeholders from several EMOs, such as first-responder organizations. These stakeholders will contribute important requirements to the analysis, participatory design, and validation of project deliverables. The design of the EMCR aims to actively involve all stakeholders who will use the system. Further work will also discuss the challenges related to this active user participation, and more will contribute to the discussion on when active full participation should be included in the development work (Pilemalm et al., 2007). Finally, further research will explore user participation with the ways in which a feedback mechanism can be used to collect comments about the tools and coordination aspects.

ACKNOWLEDGMENTS

This study was made possible by several EM stakeholders in Norway. The authors would, therefore, like to thank all the informants for their time and assistance.

REFERENCES

Asadzadeh, A., Pakkhoo, S., Saeidabad, M. M., Khezri, H., & Ferdousi, R. (2020). Information technology in emergency management of COVID-19 outbreak. *Informatics in Medicine Unlocked*, 21, 100475.

Alexander, D. (2005). Towards the development of a standard in emergency planning. *Disaster Prevention and Management*, 14(2), 158–175.

Argyris, C. & Schön, D. A. (1978). *Reading Organizational Learning: A Theory of Action Approach*. Addison Wesley, MA.

Balcik, B., Beamon, B. M., Krejci, C. C., Muramatsu, K. M., & Ramirez, M. (2010). Coordination in humanitarian relief chains: Practices, challenges, and opportunities. *International Journal of Production Economics*, 126(1), 22–34.

Bennett, D., Phillips, B. D., & Davis, E. (2017). The future of accessibility in disaster conditions: How wireless technologies will transform the life cycle of emergency management. *Futures*, 87, 122–132.

Berlin, J. M. & Carlström, E. D. (2008). The 90-second collaboration: A critical study of collaboration exercises at extensive accident sites. *Journal of Contingencies and Crisis Management*, 16(4), 177–185.

Besiou, M., Stapleton, O., & Van Wassenhove, L. N. (2011). System dynamics for humanitarian operations. *Journal of Humanitarian Logistics and Supply Chain Management*, 1(1), 78–103.

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, 49–65.

Boin, A., Brown, C., & Richardson, J. (2019). Analysing a mega-disaster: Lessons from Hurricane Katrina. Report retieved at: Retrieved from https://www.researchgate.net/

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, 9(2).

Burkle, F. M., Redmond, A. D., & McArdle, D. F. (2012). An authority for crisis coordination and accountability. *The Lancet*, 379(9833), 2223–2225.

Cannon-Bowers, J. A. & Salas, E. (2001). Reflections on shared cognition. *Journal of Industrial, Occupational and Organizational Psychology and Behavior*, 22(2), 195–202.

Carlström, E., Berlin, J., Sørensen, J. L., & Magnussen, L. I. (2019). Collaboration exercises in emergency work: Outcomes in terms of learning and usefulness. *Disaster, Diversity, and Emergency Preparation*, 146, 147–154.

Chen, R., Rao, H. R., Sharman, R., Upadhyaya, S. J., & Kim, J. (2010). An empirical examination of IT-enabled

emergency response: The cases of Hurricane Katrina and Hurricane Rita. *Communications of the Association for Information Systems*, 26(1), 8.

Crichton, M. T., Ramsay, C. G., & Kelly, T. (2009). Enhancing organizational resilience through emergency planning: Learnings from cross-sectoral lessons. *Journal of Contingencies and Crisis Management*, 17, 24–37.

Dearstyne, B. (2007). The FDNY on 9/11: Information and decision making in crisis. *Government Information Quarterly*, 24, 29–46.

Ditlev-Simonsen, C. D. & Wenstøp, F. (2013). How stakeholders view stakeholders as CSR motivators. *Social Responsibility Journal*, 9(1).

Endsley, M. R., Bolstad, C. A., Jones, D. G., & Riley, J. M. (2003). *Situation Awareness Oriented Design: From User's Cognitive Requirements to Creating Effective Supporting Technologies.* In Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications, Los Angeles, CA, 268–272.

Gjørv, A. B. (2012). Rapport fra 22. Juli-kommisjonen (report after 22 of July). Retrieved from https://www.regjeringen.no/contentassets/bb3dc76229c64735b4f6eb4dbfcdbfe8/no/pdfs/nou201220120014000ddpdfs.pdf

Gjøsæter, T., Radianti, J., & Chen, W. (2020). *Towards Situational Disability-Aware Universally Designed Information Support Systems for Enhanced Situational Awareness*. In Proceedings of the 17th ISCRAM Conference -Blacksburg VA, USA.

Gjøsæter, T., Radianti, J., & Chen, W. (2021). Universal design of ICT for emergency management from stakeholders' perspective. *Information Systems Frontier*, 23, 1213–1225.

Greenwood, F., Howarth, C., Poole, D. E., Raymond, N. A., & Scarnecchia, D. P. (2017). *The Signal Code: A Human Rights Approach to Information during Crisis.* Harvard Humanitarian Initiative Signal Program on Human Security and Technology. Retrieved from https://hhi.harvard.edu/publications/signal-code-human-rights-approach-information-during-crisis

Imoussaten, A., Montmain, J., & Mauris, G. (2014). A multicriteria decision support system using a possibility representation for managing inconsistent assessments of experts involved in emergency situations. *International Journal of Intelligent Systems*, 29(1), 50–83.

Joint Rescue Coordination Centre. (2021). Evaluation: The rescue operation and the emergency management during the landslide at Gjerdrum. Retrieved from https://www.hovedredningssentralen.no/evalueringsrapport-kvikkleireskredet-pa-gjerdrum/

Kapucu, N., Arslan, T., & Demiroz, F. (2010). Collaborative emergency management and national emergency management network. *Disaster Prevention and Management*, 19(4), 452–468.

Kusumastuti, R. D., Arviansyah, A., Nurmala, N., & Wibowo, S. S. (2021). Knowledge management and natural disaster preparedness: A systematic literature review and a case study of East Lombok, Indonesia. *International Journal of Disaster Risk Reduction*, 58, 102223.

Lee, Y.-I., Trim, P., Upton, J., & Upton, D. (2009). Large emergency-response exercises: Qualitative characteristics-A survey. *Simulation & Gaming*, 40, 726–751.

Lindell, M. K. & Prater, C. S. (2003). Assessing community impacts of natural disasters. *Natural Hazards Review*, 4, 176–185.

Matsuda, Y. & Okada, N. (2006). Community diagnosis for sustainable disaster preparedness. *Journal of Natural Disaster Science*, 28(1), 25–33.

McNeese, M. D., Pfaff, M. S., Connors, E. S., Obieta, J. F., Terrell, I. S., & Friedenberg, M. A. (2006). *Multiple Vantage Points of the Common Operational Picture: Supporting International Teamwork*. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting, Los Angeles, 50(3), 467–471.

Molka-Danielsen, J., Prasolova-Førland, E., Fominykh, M., & Lamb, K. (2018, December). *Use of a Collaborative Virtual Reality Simulation for Multi-Professional Training in Emergency Management Communications*. In 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), 408–415.

Morey, J. C., Simon, R., Jay, G. D., Wears, R. L., Salisbury, M., Dukes, K. A., & Berns, S. D. (2002). Error

reduction and performance improvement in the emergency department through formal teamwork training: evaluation results of the MedTeams project. *Health Services Research*, 37, 1553–1581.

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 ISCRAM Conference – València, Spain

Neville, K., Ó Riordan, S., Pope, A., & Ó Lionáird, M. (2018, December). *Evaluating an Emergency Management Decision Support System with Practitioner-Driven Scenarios: Action Design Research.* In Proceedings Thirty Ninth International Conference on Information Systems (ICIS), San Francisco, USA, 13–16.

Oloruntoba, R., Sridharan, R., & Davison, G. (2018). A proposed framework of key activities and processes in the preparedness and recovery phases of disaster management. *Disasters*, 42(3), 541–570.

Perry, R.W. & Lindell, M. K. (2003). Preparedness for emergency response: Guidelines for the emergency planning process. *Disasters*, 27(4), 336–350.

Pilemalm, S., Lindell, P.-O., Hallberg, N., & Eriksson, H. (2007). Integrating the rational unified process and participatory design for development of socio-technical systems: A user participative approach. *Design Studies*, 28(3), 263–288.

Pilemalm, S., Radianti, J., Munkvold, B. E., Majchrzak, T. A., & Steen-Tveit, K. (2021, May). *Turning Common Operational Picture Data into Double-loop Learning from Crises–Can Vision Meet Reality?* In Proceedings of 18th ISCRAM Conference, Virginia Tech, Blacksburg, USA. p. 417-430

Pilemalm, S., Andersson, D., & Mojir, K. Y. (2014). Enabling organizational learning from rescue operations: The Swedish rescue services incident reporting system. *International Journal of Emergency Services*, 2(3).

Radianti, A. Gjøsæther, T. & Chen, W. (2021). *Slaying the SA-Demons – Humans vs. Technology – A Content Analysis*. In Proceedings of the 18th ISCRAM Conference, Virginia Tech Blacksburg, USA.

Radianti, J., Martinez, S. G., Munkvold, B. E., & Konnestad, M. (2018). *Co-Design of a Virtual Training Tool with Emergency Management Stakeholders for Extreme Weather Response.* In Proceedings of the International Conference of Design, User Experience, and Usability.

Reddick, C. (2010). Information technology and emergency management: Preparedness and planning in US states. *Disasters*, 35(1), 45–61.

Resick, C. J., Murase, T., Bedwell, W. L., Sanz, E., Jiménez, M., & DeChurch, L. A. (2010). Mental model metrics and team adaptability: A multi-facet multi-method examination. *Group Dynamics: Theory, Research, and Practice*, 14(4), 332–349.

Rossel, P. O., Herskovic, V., & Ormeño, E. (2016). Creating a family of collaborative applications for emergency management in the firefighting sub-domain. *Information Systems Frontier*, 18, 69–84.

Rouse, W. B., & Morris, N. M. (1986). On looking into the black box: Prospects and limits in the search for mental models. *Psychological bulletin*, *100*(3), 349.

Santos, R. S., Borges, M. R., Gomes, J. O., & Canós, J. H. (2008). *Maturity Levels of Information Technologies in Emergency Response Organizations*. In International Workshop of Groupware, Springer, 135–150.

Soden, R. & Palen, L. (2018). *Informating Crisis: Expanding Critical Perspectives in Crisis Informatics*. In Proceedings of the ACM on Human-Computer Interaction (CSCW), 2, 1–22.

Snaprud, M., Radianti, J., & Svindseth, D. (2016). *Better Access to Terminology for Crisis Communications.* In Proceedings of the International Conference on Information Technology in Disaster Risk Reduction, Springer, Cham, 93–103.

Steen-Tveit, K., Radianti, J., & Munkvold, B. E. (2020). *Using Audio-Logs for Analyzing the Development of a Common Operational Picture in Multi-Agency Emergency Response*. In Proceedings of the 53rd Hawaii International Conference on System Sciences (HICCS), USA.

Steen-Tveit, K. (2020). *Identifying Information Requirements for Improving the Common Operational Picture in Multi-Agency Operations.* In Proceedings of the 17th ISCRAM Conference, Virginia, USA.

Steen-Tveit, K., & Munkvold, B. E. (2021). From common operational picture to common situational

understanding: An analysis based on practitioner perspectives. *Safety science*, *142*, 105381.

Steen-Tveit, K. (2022). *From Common Operational Picture to Common Situational Understanding : A Framework for Information Sharing in Multi-Organizational Emergency Management.* (PhD. Thesis at the University of Agder). Retrieved at: https://uia.brage.unit.no/uia-xmlui/handle/11250/3027118

Uutilsynet.no Retrieved at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016L2102

Valecha, R. (2019). An investigation of interaction patterns in emergency management: A case study of the crash of continental flight 3407. *Information Systems Frontiers*, 22(4), 897–909.

Van de Walle, B. & Comes, T. (2015). On the nature of information management in complex and natural disasters. *Procedia Engineering*, 107, 403–411.

Wang, L., Zhao, N., & Liu, D. (2020). Complex disaster management: A dynamic game among the government, enterprises, and residents. *Journal of Cleaner Production*, *266*, 122091.

Walle, B. V. D. & Turoff, M. (2008). Decision support for emergency situations. In *Handbook on Decision Support Systems*, 2, Springer, Berlin, Heidelberg, 39–63.

Waring, S., Alison, L., Carter, G., Barrett-Pink, C., Humann, M., Swan, L., & Zilinsky, T. (2018). Information sharing in interteam responses to disaster. *Journal of Occupational and Organizational Psychology*, 91, 591–619.

Waterman, L., Rivas Casado, M., Bergin, E., & McInally, G. (2021). A mixed-methods investigation into barriers for sharing geospatial and resilience flood data in the UK. *Water*, *13*(9), 1235.

Yen, J., Fan, X., Sun, S., Hanratty, T., & Dumer, J. (2006). Agents with shared mental models for enhancing team decision makings. *Decision Support Systems*, 41, 634–653.