A structured and dynamic model for emergency management exercises

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ABSTRACT

Emergencies are management challenges, and emergency exercises that involve multiple collaborating parties is a means towards mastering them. Such exercises are often conducted in a virtual training environment based on complex disaster scenarios. The reported study was carried out using a requirement-focused design approach. The aim was to describe and discuss a relevant design for lean, dynamic, and cost-efficient emergency management exercise systems. Data were gathered from a literature study and analyses of earlier emergency management projects in which the authors had participated. Despite the complexity of many current emergency management exercises, the scenarios usually involve only the response phases and have a linear structure that hinders both didactic aspects and the software structure. The conclusion drawn from the study is that an emergency management exercise model should focus on managing the activities that correspond to alternatives that unfold from a dynamic scenario. Finally, the authors recommend the principles of alternate reality games as a way towards more dynamic and cost-efficient emergency exercise systems.

Keywords

Emergency management exercises, vulnerability assessment, non-linear emergency exercise model, Norwegian–Swedish cross-border collaboration, gaining security symbiosis (GSS) projects.

INTRODUCTION

Emergencies ranging from everyday events to large-scale disasters pose management challenges. Different emergencies create different demands with respect to response organizations and to the solutions to the tasks at hand. The notion of four disaster phases—preparedness, response, recovery, and mitigation—has been a guiding framework for emergency management and emergency research since the 1970s. Researchers have used these categories to organize their findings, while practitioners have relied on them in efforts to improve their capacity to manage emergencies (Neal, 1997; Adams, 2002). Briefly, *preparedness* is about planning and training for managing emergencies, r*esponse* concerns taking actions to prevent harm when the emergency occurs, *recovery* refers to measures taken to normalize the situation and increase safety, and *mitigation* is about preventing emergencies (Neal, 1997).

Emergency response organizations, such as police, fire services, and ambulance and emergency units, usually focus their training efforts on preparedness and response, whereas significantly fewer exercises concern mitigation and recovery. Exercises for all four emergency management phases (Figure 1) can be carried out as part of full-scale emergency exercises or as desktop exercises with varying levels of complexity and sophistication regarding simulation and data equipment. In this paper we explore the general requirements for structuring an emergency management exercise system that is *lean*, in the sense of sparse with respect to the system development efforts needed and the requirements for specialized equipment that are reusable and dynamic, and thus cost-efficient.

In central Scandinavia, neighboring counties close to the border between Sweden and Norway share several challenges. The border region is large and has a small population. At 53,120 km^2, the area of the border municipalities in the counties of Trøndelag and Jämtland is larger than, for example, Switzerland (Figure 4), and

in 2020 the population of the border municipalities was only 83,330 and decreasing (Statistics Norway, 2021; Statistics Sweden, 2021). The high number of tourists places a disproportionate burden on health services and rescue services. Distances are long and in the case of an emergency, the nearest form of assistance may be located across the border. Hence, these are strong incentives for transboundary collaboration in the field of emergency response. The research reported in this paper has been carried out in the three phases (2011–2014, 2015–2018 and 2018–2021) of the research project Gaining Security Symbiosis (GSS), which was run jointly between Sweden and Norway, with the aim of gaining new knowledge about cooperation between central risk and crisis actors in Sweden and Norway. The project members have been responsible for arranging several emergency exercises and have observed and evaluated other. The overall goal of the ongoing project is to contribute to increased security for residents and visitors to the border region.

An identified problem that motivated the study is that the relatively expensive crisis management exercises have had weak results and poor learning outcomes (Borodzicz & Van Haperen, 2002; Borell & Eriksson, 2013). Furthermore, in exercises the emphasis has tended to be placed on the operational crisis management, while the ability to deal with the far-reaching consequences of crisis situations has been neglected. The exercise concept needs to be developed to include, also the preventive and recovery phases, which in practice implies that more actors need to be included (Kvarnlöf et al., 2017). Exercises are repeatedly mentioned as an important activity, but time and opportunity are limiting factors (Borglund & Granholm, 2020). COVID-19, which has prevented the implementation of exercises involving a physical presence, has increased the relevance of crisis management exercises.

Conventional response exercises are necessary to build preparedness. However, in effect, an additional demand exists for flexible training arrangements that allow for other than search and rescue organizations to engage and for persons with a variety of responsibilities to "meet" and train.

ITC tools may be a means of bringing more people together for exercise purposes, as they can facilitate processes across geographical distances, allowing for collaboration, instruction, and learning. This has been and still is at the core of the GSS projects. As the ability to respond to unknown specific threats may be viewed as depending on the general level of preparedness, ITC tools developed for emergency exercises typically fall between two extremes. According to the Federal Emergency Management Agency in the USA, they can be very specific, such as the "Cyber Ready Community Game" (FEMA, 2020a), which was developed to allow organizations to explore how to protect essential services against cyber incidents within certain limiting factors, such as budget and time constraints and available facilities. At the opposite end of the spectrum, also from FEMA, there is the "Preparedness Toolkit" (FEMA, 2020a), which is a set of generic tools that allow organizations to facilitate their own exercises such as workshops and tabletop exercises. The GSS Emergency Exercise system (Asproth et al., 2014) has a similar focus, allowing participating organizations to prepare and conduct their own exercises remotely.

GSS1, the first GSS project, aimed to create an emergency exercise facilitation system prototype based on conventional web-technologies. The system's main purpose was to allow the researchers to gain insight into communication issues across languages, professions, and physical barriers. In GSS2 the prototype was further developed to allow researchers and stakeholders to carry out distributed emergency exercises, and thus not requiring participants to be absent from their daily tasks at their local workplaces. The third iteration of the project, GSS3, has aimed to evaluate the results of the two prior projects and target the further development efforts accordingly.

The aim of the study presented in this paper was to describe and discuss relevant design topics for a lean, dynamic, and cost-effective emergency exercise system. Exercise systems of this type are not common. The important research question to answer was what the general structural requirements could be for a lean, reusable, dynamic, and cost-efficient emergency training system.

The results from an analysis of earlier GSS projects and the literature study contributed some preliminary guidelines for improving the current emergency exercises. These guidelines, which we concretize in a framework for exercises (Figure 5), should be regarded in the next generation of emergency exercises in cross-border collaboration between Norway and Sweden. It would be of interest for future research to evaluate emergency response exercises in which these guidelines are implemented.

EXTENDED BACKGROUND

To summarize some key background topics, we have divided this background section into three parts (subsections). The first part looks at several theoretical models for disaster and emergency event management. In the various GSS projects, the choice has been the globally well-known emergency management cycle, also known as the FEMA model (FEMA, 2020b), in which emergency management is viewed as a cyclic process. In the

second part, cross-sectoral collaboration is explained as an important principle in the sparsely populated central Scandinavian counties along the border between Sweden and Norway. Involvement of more stakeholder groups in exercises may make emergency services response more effective, and it may lay the foundation for encompassing the recovery and mitigation phases of the emergency management cycle. Lastly, in the third part we focus on alternate reality game design as an interesting area that might have concepts that can be used to reinforce current emergency exercises.

The emergency management cycle

To understand the dynamics of disasters and emergencies, the identification of emergency phases has been an important approach used by both practitioners and scholars since the 1930s (Neal, 1997). Carr (1932) argues that all social change, including that which is forced upon a community by a disaster, follows a distinct sequential pattern. Disasters start with a preliminary period during which the destructive forces are under way. The next phase is a dislocation and disorganization period in which disaster strikes. This phase passes into a readjustment and reorganization phase, a third phase during which the community responds to the impact and institutionalized agencies gradually become involved. In events in which the coordination of community life is disrupted, a fourth phase, a phase of delayed confusion, lasts until recovery plans start to have an effect and readjustment is set in motion and continues until a new equilibrium is reached.

There are several models for emergency management, each with specific advantages and drawbacks. Haas et al. (1977) hold that preparation, response, recovery, and mitigation are four distinct functions, not temporal phases, that need to be managed to avoid events or reduce the impact. These lines of thought have been incorporated in the emergency management cycle (FEMA, 2020b) that is based on the National Governors Association's guide to Comprehensive Emergency Management (Whittaker et al., 1979). According to the guide, emergency-related activities tend to cluster into phases that are related by time and function, and that are relevant for all types of disasters. These activity clusters are mitigation, preparation, response, and recovery. The cyclic activity orientation of the model differs from the rather deterministic sequence pattern argued by Carr (1932), both by leaving more room for human agency and by placing emphasis on planning and training as ways forward to be better prepared for the next emergency. The model has since been adopted by Scandinavian authorities and the FEMA, among other. It has also been modified to encompass activities or functions not anticipated by the National Governors Association.

Our study was based on the ambition that emergency management exercises should be structured to encompass all phases of the FEMA model. The phase order differs in research studies (Neal, 1997; Adams, 2002), but according to the FEMA the phase order is (1) Preparedness, (2) Response, (3) Recovery, and (4) Mitigation, as depicted in Figure 1:

1) Preparedness:

   The essence of this phase is to take the risk that has been identified and, after mitigating it, start to prepare for all kinds of scenarios, even the unthinkable. If a disaster occurs, the involved stakeholders should be able to get through it safely, and to respond effectively.

2) Response:

   This phase begins when a state of emergency threatens or is detected. All prepared plans should be put into action, involving the mobilization of staff, and the positioning of emergency equipment.

3) Recovery:

   This phase consists of the rebuilding after a disaster, a long-term process in which the public and private sectors work together. The phase also includes psychological counselling for disaster survivors and the relatives of those who did not survive.

4) Mitigation:

   FEMA describes mitigation efforts as "those which try to eliminate or reduce the impact of a hazard, such as the traditional lightning rod," and as the actions "taken to reduce or eliminate the long-term risk to human life and property from natural hazards" (FEMA, 2020b)

Figure 1. The FEMA four phase emergency management cycle (FEMA, 2020b).

Cross-sectoral collaboration

Emergency exercises are considered by both researchers and practitioners as a valuable tool for testing and strengthening emergency management capacity. In a review of studies of emergency exercises, Kvarnlöf et al. (2017) argue that emergency management and emergency exercises have become more complex and cross-sectoral. However, there is still an overrepresentation of accident scene exercises. Kvarnlöf et al. (2017) advocate that exercises concepts should be developed to include the preventive and recovery phases and that actors with diverse backgrounds need to be included in exercises. In an explorative study of how actors from different backgrounds may contribute differently to dealing with emergency situations, Danielsson (2016) investigated how personnel from the police, the emergency services, and a nursing home would act in potentially dangerous situations. She found that the positive contribution from lay people's understanding of emergency situations, based on their knowledge, might make responses more effective. When emergency organizations are called in to handle emergency situations, they enter organizational fields of which they have little knowledge and in which they meet people with good knowledge of the field but with limited knowledge of emergencies. Emergency response professionals respond to what is known to them and therefore need to train in emergency situations together with people from other groups in order to gain access to knowledge about their home grounds. Emergencies often take place in settings that are workplaces or otherwise familiar grounds to other groups than the emergency professionals, and cross-sectoral training will raise awareness and knowledge of unfamiliar situations among the professionals and increase competence about emergency situations among the other groups that participate.

Alternate reality games

As in the case of certain types of computer games, immersion is an important element of virtual emergency exercises to stimulate engagement and quality learning outcome. As pointed out by Y. F. Chen et al. (2008), small-scale individual-task training exercises in highly controlled environments could decrease realism and immersion. At the same time, it has been reported that complex and costly emergency exercises have not delivered the expected learning outcomes (Kvarnlöf et al., 2017). For emergency exercises, as an alternative genre to educational games, alternate reality games (ARG) may be an interesting, realistic, and lean alternative.

In the space between costly high realism simulations and oversimplified cheap games, ARGs are designed to challenge the player with real-world tasks instead of multimedia extensive fantasy game worlds. ARGs should be designed for the player to get more out of real life, as opposed to fantasy games that are played to escape reality. As a genre, ARGs involve several learning stimulating elements, such as realistic and immersive narration, problem solving, and collaborative learning with peer communication (Moseley, 2012). The combination of story-driven game structures in ARGs (Stenros et al., 2011), and the ARG potential of acting as virtual platforms for collaborative learning (Bonsignore et al., 2012), makes the ARG concept a promising source of inspiration for the design of lean and cost-efficient digital emergency exercises.

For our study, the ARG genre is a promising approach and allows for the ambition that emergency management exercises can take place on different platforms depending on the situation and the role of the participants, and that participants will be able to alter the narrative during the exercise. Thus far, our framework has not been fully developed as an ARG exercise.

METHOD

The study was conducted with an approach inspired by the design science framework outlined by Johannesson and Perjons (2014), which is reproduced in Figure 2.

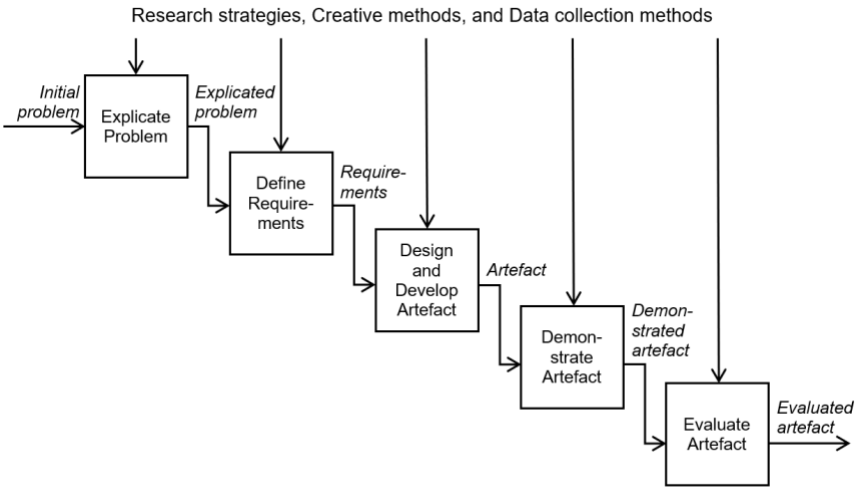

Figure 2. Phases in the design science research framework. Adapted from Johannesson & Perjons (2014, p. 77).

Design science studies do not always involve all five phases of the method framework depicted in Figure 2. Our study was conducted as a requirement-focused design science project, with a focus on the first two phases only: explicating the problem and defining the requirements. This type of design science study starts with an existing problem, explicates the problem and defines the requirements for building a new artefact or updating an existing artefact. In requirement-focused design science research, the artefact design is only outlined and does not involve artefact demonstration or artefact evaluation (Johannesson & Perjons, 2014). Extending the study by going through with the third, fourth and fifth phases, respectively developing the artefact prototype, testing it in an exercise, and evaluating the outcome, was first carried out in February 2021 and will be reported later.

Data collection

Data were gathered through a combination of a literature study and analyses of data from earlier GSS projects. The gathering of requirements was done with the aim of creating a foundation for future work, in which the remaining phases shown in Figure 2 will be executed. This future work will involve the updating and evaluation of the training system that has been developed in the earlier projects, GSS1 and GSS2. The literature study focused on the FEMA cycle, cross-border collaboration, and alternate reality games, and the findings are presented above, in the section "Extended background."

Communications data from emergency exercises were ordered chronologically and analyzed using content analysis (Hsieh & Shannon, 2005). For this paper, we investigated emergency radio communication from the Norwegian-Swedish ISI (Inter-System Interface) exercise conducted in November 2016 that was monitored as part of the GSS2 project.

The ISI 2016 exercise comprised two incidents: (1) a bus accident in Norway involving a Norwegian bus, a Swedish bus, and a stolen Norwegian car that left the scene in the direction of Sweden; (2) a subsequent accident in Sweden, where the stolen car had been driven into the ditch, and the driver and potentially any injured passengers had fled the scene. A total of 1015 radio voice calls within 196 communication exchanges were analyzed. Categories of calls and exchanges were developed based on the data, rather than defined beforehand. Several communication exchanges might have taken place simultaneously, and the individual communication threads were identified through the content analysis. For the second of the incidents, police moved their communication to a talk group that the project did not monitor, and consequently our records of this part of the exercise are less complete, and with a blind spot on the coordination of search activities that was taking place at the scene of the second incident. At the scene of the bus accident, most communication was spoken person to person. During exercises, it is known that some radio communications were often conducted using other communication channels than Nødnett-Rakel talk groups. for example, personnel use cell phones when talk groups

are crowded or to send photos of an incident. During the ISI exercise, however, cell phone communication was difficult due to poor mobile coverage.

EXPERIENCES FROM PREVIOUS GSS PROJECTS

During the GSS1 and GSS2 projects, a team from Nord University and Mid Sweden University made efforts to create a digital, web-based emergency management training system. The computer-based training tool consisted of well-known, industry-standard, open web technology (Linux, Apache webserver, MySQL database, and PHP server-side scripting). Participants in the projects included personnel from all levels within central Scandinavian emergency response organizations (operational, tactical, and strategic levels representing the supply side, and participants representing the demand side), the municipalities, county officials, and electric power companies (Asproth et al., 2014, Ekker, 2016).

The GSS emergency exercise system presents an emergency scenario to respond to and allow for communication between the participants who may be in their everyday working environment. To date, scenarios have been conventionally highly structured. They have included different types of media elements to illustrate or give specific information about the scenario events. The system has been built to record written communication between the participants, aggregate data about how the participants collaborate and communicate, and to allow for different ways of presenting information about the exercise. The main purpose of the data recording during the exercises has been to investigate how different parties communicate across organizational, language, and regional boundaries, and national borders.

The modelling concept for the GSS1 and GSS2 emergency exercise system uses a linear model (Figure 3), based on a generalized idea of the progress of an exercise or a catastrophic event. The model uses a fixed scenario manuscript and set of events, and the participants' goal is to respond to one situation or event at the time. New situations and events are strictly monitored and managed by the exercise management team.

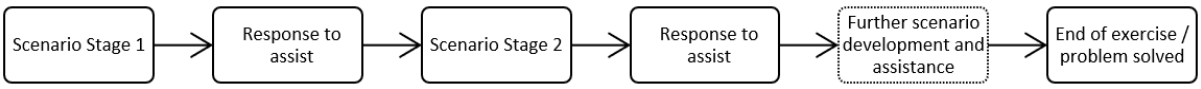

Figure 3. Linear model for developing the front end of the emergency exercise used in GSS1 and GSS2.

Exercise scenarios usually involve several elements, with the intention to stretch the capacities of the participating organizations and stimulate collaboration. In the context of Norway and Sweden, the scenario events usually will be located near the border, and the events will ideally have a character that make them shared responsibilities and that involve victims from both countries. This will require participants to open communication that extends beyond the normal chains of command to agencies across the border. Subsequent developments to the exercise will add new tasks that further stretch capacities and that demand collaboration or new information to be added that require reconfiguration of the response.

From 2013 to 2016, the Inter System Interoperability for Tetra-TetraPol Networks (ISITEP) project aimed to improve cross-national emergency communication in Europe. TETRA talk-group communication applied across national emergency communication systems enables half-duplex communication between personnel from different countries. This implies that a user from one country that is transmitting can be heard by all others in the same talk group, irrespective of nationality. The first operational connecting of two national TETRA systems, the Norwegian Nødnett and the Swedish Rakel, was done during a large transboundary emergency exercise in Meråker Municipality, Norway, in November 2016. The exercise that was the most thoroughly documented of all exercises documented by the GSS project. The GSS system was applied to document radio communication between the officers from Norwegian and Swedish public protection and disaster relief organizations (fire departments, emergency medical services (EMS) and regional EMS communication centers, the police, and civil protection). Five talk groups assigned for the exercise were observed.

Figure 4. Location of the November 2016 ISITEP exercise, with participating hospitals, and the counties of Trøndelag, Jämtland and Västernorrland that participated in the GSS project.

Following research on emergency radio communication, Borglund & Granholm (2020) identified the main content categories as information about the incident, communication about operational decisions, safety issues, and information and questions of a geographic nature. Our study of the recorded communication during the ISI exercise revealed that it is possible to follow distinct activities within an exercise and in many instances identify the start and termination of activities. However, the activities do not take place in an orderly sequence. After the alarm is sounded, many things happen at the same time. Consequently, it is problematic to report what is happening in terms of phases. Because many different things are ongoing simultaneously, it is more informative, and in line with Haas et al. (1977), to describe them as several distinct activities that are being managed and coordinated simultaneously. The experiences from the ISI exercises suggest that except for a distinct alarming phase, it is difficult structure events sequentially. We identified distinct tasks that were attended to, but they did not follow in chronological order (Table 1).

Table 1. Chronology and topics that were communicated on Nødnett-Rakel emergency radio during the Norwegian-Swedish ISI exercise in November 2016.

Start	Topics in radio communication	End
	Incident 1. Bus accident involving two buses, caused by persons in a stolen car who has fled the scene after the accident.	
11.07	Alarm. Accident involving two buses near the Sweden–Norway border.	11.17
11.07	Mobilization of resources.	11.40
11.11	Units move out. Communication between units about who are moving out. Preparations for what awaits the crews at the scene of the accident.	11.26
11.12	Coordination of radio communication.	13.26
11.22	First situation reports from crew at the site of the accident. Conveys scope more accurately.	11.37
11.33	Rescue. First responders move in. Coordination of resources on-site. Geographic coordination at the scene of the accident–parking, maneuvering, where to send crews and ambulances. Reporting of what different crews do. At 12.23 the operations manager for the medical units reports that he no longer has a complete overview, at 12.28 that there is chaos at the scene of the accident. Radio communication peaks between 12.40 and 12.45.	13.36
11.40	Coordination between EMS communication center and on-site incidence management. Regional incidence management informs on-site management about what resources will be available for treatment of the injured.	12.14
11.52	Transportation. Communication about transportation of the injured (vehicles, helicopters, buses) and where they are to be transported. Communication about the requirements of the injured during transportation. Directions for returning emergency vehicles and air ambulances.	13.37
12.08	Search. Communication about search for potentially missing people.	13.09
12.14	Traffic management.	13.25
12.24	Patients on the way. Coordination between ambulances and EMS communication center and hospitals about numbers of patients under transportation, the patients' condition and their destination. Communication between on-site command and EMS communication center about the number of injured and the care requirements for the injured and others who have been involved.	13.35
12.36	Rescue completed. Situation reports, all injured under transportation or waiting for transport, reports of mortalities. Communication about catering for the personnel.	13.28
12.38	Clearance work.	13.24
	Incident 2. Search for persons from the hit-and-run car.	
11.33	Alarm that stolen car that caused the bus accident escaped in the direction of Sweden.	
12.34	Escaped car identified in Sweden, redirection of police units towards location.	12.34
12.35	Mobilization of resources. Redirection of units from incident 1.	13.19
12.39	Coordination of radio communication.	12.40
12.50	Situation reports about incident, potential number of persons and injuries, search activity.	13.06
	On-site activities coordinated on police talk group that was not monitored by project.	
13.12	Direction of ambulance to the scene of the accident.	13.28
13.30	Report about apprehension of missing persons.	13.30

Communication is an essential part of the exercise, and the radio communication that can be observed reflects the events on the ground well and can be used to monitor the event. For example, the first responders tend to report by radio when an activity is terminated, and consequently, that exact time is logged. However, some blind angles exist. For example, people on scene will communicate directly with each other if possible, and the persons in charge of the different emergency response units will gather with the commander in charge on-site to discuss how to proceed. Furthermore, in some situations, the personnel will use cell phones instead of emergency radio communication. For example, during the Norwegian-Swedish ISI exercise in 2016, despite poor mobile coverage, cell phones were used to transmit photo-documentation.

When the alarm is sounded, resources are mobilized and coordinated, and information about the incident is exchanged. Thus, a distinct introductory phase can be observed. The ending of the exercise also has distinct features characterized by communication about activities such as clearing up the scene and letting traffic through. However, the overall picture is that communication splits into many threads that simultaneously guide and follow the different activities that take place. Information about the units and their work is transmitted throughout the operation, as are operational decisions.

The GSS emergency exercise system allows for documentation of communication and for graphical presentation. However, in order to learn from what has taken place during an exercise and to understand how decisions are made and events evolve, it is desirable to be able to follow the individual communication threads. However, because the system is structure linearly and not designed to differentiate between communication threads, this will be difficult and time consuming.

We have elaborated on how emergency exercises tend to be highly scripted and structured, and focused on improving preparedness capacity through exercising response. Usually, exercises involve only the agencies and offices with direct responsibilities during emergencies, while the public are the object of rescue or assistance.

Considering the present COVID-19 crisis, pandemics tend to score high on both likelihood and impact in risk matrixes. Hence, it could be expected that response organizations are prepared for such specific events. However, during the crisis the whole population has taken responsibility to reduce spread of the disease. This demonstrates that the regular crisis response apparatuses need to collaborate with lay persons and organizations during crises. The COVID-19 pandemic has also demonstrated the adequacy of systems that facilitate emergency management exercises that do not require participant to be gathered at the same place.

The GSS emergency exercise system requires those who participate in an exercise to make decisions on how to manage a developing situation as it is presented in a scenario. Responses are given in writing and must be directed to a receiver, which may be other units in the participant's own organization or in other organizations. Typically, exercises set up complex temporal scenarios based on a finite number of singular events, in which a limited number of persons are involved in activities based on one or few individuals' perceptions of that event. The linearity of the system requires that the scenario stimulates a certain response that leads to the next scenario element, and so forth, in a manner that is consistent with existing emergency response plans. This makes it difficult for an exercise to sidetrack into alternative but conceivable courses of action. It also makes it difficult to include the element of uncertainty that is involved in collaborating with groups from outside the professional apparatus, who may respond in ways that conflict with the exercise playbook. Last, linearity of the system rules out the long-term and often political perspectives involved in recovery and mitigation.

The GSS project has shown that a lean emergency exercise system can add elements to emergency management exercises that are innovative, such as distributed training and facilitation for asynchronous training. However, for the reasons outlined above, it is not well adapted for the many divergent scenarios that may unfold from one emergency, and it is not adapted for collaboration across the divide between professional responders and other impacted groups or officials who must be involved in longer term processes.

DISCUSSION

In the perspective that emergency management is full cycle, also encompassing the recovery and mitigation phases, we argue that emergency management training should facilitate involvement of a broad range of participants, including civil groups together with the emergency response organizations. During training, participants should interact, aiming towards finding solutions to mitigation, preparedness, response, and recovery challenges. Mitigation, preparedness, response, and recovery cannot be fully trained in one exercise. Nevertheless, we need training methods with an all-encompassing potential, and that facilitate exploration of many types of difficult emergency situations. Furthermore, a broad range of participants should be involved in finding solutions to the challenges.

To stimulate cross-sectoral collaboration (Danielsson, 2016), we suggest a model based on the following premises:

a) Emergency management is about decisions, communication, and coordination regarding distinct but parallel activities.

b) Learning from exercises will be enhanced through access to the individual threads of communication.

c) Mitigation, preparedness, response, and recovery are included.

d) Stakeholders other than professional emergency response organizations participate.

We suggest a practice based on questions that allow for exploration of emergency situations involving different

stakeholder groups. Each group would explore the vulnerabilities that from their perspective may ensue from a scenario, and elaborate the responses that each vulnerability calls for, short-term and long-term. In that context, vulnerability would mean susceptibility to harm (Adger, 2006). The questions that we propose are:

1. What will happen if?

   A scenario is presented for the participants.

2. How will events unfold?

   Participants reason and discuss the situation to explore potential development of the situation, as relevant for the group they are representing.

3. Who are vulnerable in the situation?

   Participants make assessment and identify vulnerabilities, as relevant for the group they are representing.

4. Who will respond, and how?

   Participants identify responsibilities regarding the situation and determine alternative/complementary courses of action to mitigate or alleviate the imminent situation.

5. What can we learn so far?

   Evaluation. Identify resources, operation and collaboration needed to manage situation. Alternatively, identify resource gaps, inoperativeness and barriers to collaboration that worsen the situation.

A framework for how an exercise built around these questions may proceed is depicted in Figure 5. Repetition of the procedure allows for exploration of the new situation based on first iteration and so on. The scenario for a further iteration should, in line with ARG principles, be adapted to the outcome of the previous iteration. By following this routine, participants in exercises will collaboratively be able to build scenarios based on sparse initial inputs rather than follow a linearly scripted manual, and they will be able to explore vulnerabilities and feasible short-term and long-term responses.

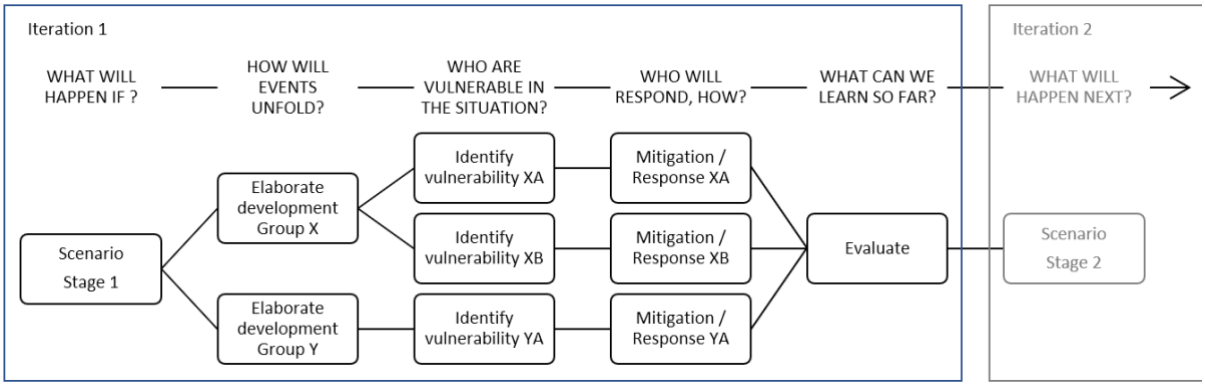

Figure 5. Framework leading towards a structured dynamic model for cross-sectoral emergency and vulnerability exploration.

Our suggestion is that lean and cost-efficient emergency exercises could be built around the principles used in alternate reality games (ARGs) and found in the literature study, and that these principles could be implemented in the next version of the GSS technological platform for emergency exercises. Emphasis should be on developing slim, flexible, and asynchronous emergency training systems that allow users to modify scenarios without changes having to be made to the program code. The structure should also prevent the issue with exercises that become obsolete in just a few years and instead allow parts of scenarios mapped to phases in the FEMA cycle to be reused in new emergency exercise scenarios.

Furthermore, it seems important to stick to the fundamental ARG ideas about realism and immersion, but also to extend the concept of individual tasks (Y. F. Chen et al., 2008) to collaborative exercises with rich peer communication opportunities (Moseley, 2012). It might also be of interest to try to increase exercise participants' engagement by adding the motivational effect identified in digital game-based learning (Y. C. Chen, 2017; Breien & Wasson, 2020). Our recommendation is to design virtual emergency exercises with the modern serious game

idea of building games designed for a purpose beyond entertainment, but that despite the serious purpose the games should still be entertaining and fun (Wilkinson, 2016).

CONCLUSIONS

Our study aimed at describing a relevant design for a lean, dynamic, and cost-efficient emergency exercise system, by asking what the general requirements for the structuring of such a system could be. Emergency management exercises, including those in which the GSS project has been involved, tend to focus on building preparedness by training emergency response among professional responders. Scripted in accordance with emergency management plans, the exercises have limitations regarding involving other stakeholder groups and regarding the long-term perspectives of recovery and mitigation. For these reasons, there is a need for cross-sector emergency management training that encompasses recovery and mitigation.

The suggested lean and cost-efficient emergency management exercise model should have a focus on management activities that correspond to the alternatives that unfold from a dynamic scenario. Experience, if acted upon, can reduce procedural frustration in times of emergency, when responsible, fast decisions and follow-up are needed, and thus improve future preparedness and response.

Based on the findings and suggestions presented in this paper, a novel and improved approach to emergency management exercises could be to incorporate not only the linear exercise scenario with a subsequent debriefing, but also the preliminary exploration of the situation and its inherited risks and vulnerabilities. A natural extension of this approach would be to add a structured review of the entire exercise, and the participants' responses to the events and development of the scenarios during the exercise. Such a review could then be used as direct input to improve future exercises based on the same general structure.

According to the design science framework depicted in Figure 2, the next steps will be to (1) implement the insights from the study presented here, and (2) demonstrate and evaluate the artefact. Based on the vulnerability exploration, and with inspiration from the studied alternate reality game principles, new scenarios should be created and tested by various stakeholders in emergency management. The plan is to carry this out during the final part of the GSS3 project with a user test administered during the Norwegian-Swedish Border Rescue Council (Grenseredningsrådet) meeting in 2021.

ACKNOWLEDGMENTS

We thank personnel in the emergency response organizations in central Scandinavia and the Border Rescue Council (Grenseredningsrådet), who have contributed with their knowledge and experience throughout the GSS project. We also thank Interreg Sweden – Norway for financing this research.

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