

Unified Effort: Developing a Mixed Reality Serious Game for Collaborative Crisis Management Training

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Abstract: Crises and disasters include both predictable and unpredictable events. In a turbulent world that has recently experienced a pandemic and wars, and is increasingly affected by climate change, there is a growing need to develop effective public crisis management capabilities. Emergency preparedness is a critical foundation for crisis management. Training and exercises are essential components of preparedness and are becoming increasingly relevant for a wide range of organisations in society. To achieve a unified response to threatening events, a wide range of actors - with different backgrounds, objectives, competencies and organisational frameworks - must overcome the challenges of working together. To address this complex situation, forums for knowledge sharing and learning are required. Serious games in mixed reality can be used as a platform for collaborative training and serve as such a forum. Mixed reality systems connect virtual and physical reality, providing users with a sense of immersion, engagement and interaction in both environments. The aim of this paper is to design a short, serious game for collaboration training with two command levels in a mixed reality. Theories of crisis management, along with related research on serious games design, create the framework for the game. The game content was further developed in a co-design process with selected professionals. This paper describes the development of the “Unified Effort” game. The serious game is designed for basic training of municipalities and county offices in soft skills such as communication, situational awareness and group decision making. The game is not intended to replace hard skills such as procedural training and field drills, but can be used as a supplement to this type of training.

Keywords: Crisis Management, Societal Security, Training and Exercise, Serious Games, Mixed Reality, Games Based Learning

1. Introduction

In the wake of the global pandemic caused by the novel coronavirus (Covid-19), the constantly changing climate, and the general unrest in various regions of the world, there is a growing need for the development of effective public crisis management capabilities. Crises and disasters include both foreseeable and unpredicted events. Crisis management is about anticipating the former in order to minimise the latter (Di Loreto et al., 2012). Crises share several similarities with Horst and Webber’s (1973) “wicked problem” (Booth et al., 2020; Criado & Guevara-Gomez, 2021; Crivellari, 2019). Problem understanding and problem resolution are concomitant to each other. An image of the problem and of the solution emerges gradually among the actors (Horst & Webber, 1973, pp. 161-162).

Crises present governments and leaders with decisions they do not face on an everyday basis. But crisis management involves more than just “big” decisions (Boin et al., 2017). Decisions also need to be implemented, often by a diffuse network of actors. Getting things done therefore requires horizontal and vertical coordination. It is of paramount importance to ensure effective coordination in order to prevent miscommunication, unnecessary overlap and conflicts between governments, agencies and actors involved in crisis operations (2017, p. 16). The wickedness of a crisis makes collaboration both necessary and challenging.

Lack of collaboration has been identified as a key failing in several major disasters and crises. A lack of coordination between federal, state and city governments was identified as a factor contributing to the failures observed after hurricane Katrina (Cole & Fellows, 2008). For the Norwegian government, the aftermath of the terrorist attack on 22 July 2011 has been characterised by a focus on the lack of communication and coordination between government departments (Gjørø, 2012).

Emergency preparedness is a crucial basis for crisis management, and training and exercises are essential components of preparedness. The experience of personnel involved in disasters and crises has demonstrated that those with a high level of relevant competence are better able to manage the situation during and after the crisis, than those with a low level of competence (Weisæth & Kjeserud, 2021). This includes collaborative training. It is a common misconception that collaborative training is synonymous with full-scale exercises, which are fully set up with personnel and material “in the field” (Sommer et al., 2020). Despite the high level of ambition for cooperation, these exercises frequently result in each organisation practising internally within its “silo”, due to a lack of sufficient advance training (Løvik, 2010). This frequently occurs due to a lack of fundamental clarification regarding roles, responsibilities and authority. Consequently, significant

resources are expended on a task that should have been practised on a smaller scale. Based on this, there is a need for innovative ways to approach, design and implement collaboration training.

A unified response to a disaster involves a variety of stakeholders with different organisational structures and backgrounds, and sometimes competing agendas. *Forums* are needed where stakeholders can come together to improve understanding and reconcile differing views (Fleming et al., 2020). This article suggests that two-level collaboration training through serious games in a mixed reality can be such a forum. Mixed reality systems connect virtual and physical reality, providing users with a sense of immersion, engagement and interaction in both environments. Although mixed reality games have received increasing attention across multiple disciplines, their adoption in crisis management and disaster response training is limited (Alharthi et al., 2018).

The aim of this paper is to design a short, serious game for collaboration training with two command levels in a mixed reality environment. Crisis management theories, together with related research on serious games design, create the framework for the game. The game content is further developed in a co-design process with selected professionals. The paper describes the development of the game and includes a concept sketch of the game. The serious game will be empirically tested for various learning outcomes in a subsequent study.

2. Theoretical Foundations

2.1 Soft Skills for Crisis Management

Crisis management involves different kind of competencies, from very specific procedures (“hard skills”) to more generic competencies (“soft skills”). The first section highlighted the importance of collaborative actions in crisis management. Inter-disciplinary collaboration is essential when working in multi-disciplinary teams (Amaratunga et al., 2018), and research emphasises the importance of soft skills such as team working, communication, situational awareness, leadership, decision making in the face of competing demands (Bakken et al., 2017; Di Loreto et al., 2013; Radianti et al., 2020), problem-solving with partial or contradictory information (Linehan et al., 2009), time management and stress management (Di Loreto et al., 2013). Although the term “soft skills” is not commonly used in the social psychology literature, these skills have been extensively researched and are considered to play an important role in the quality of group decision making (Linehan et al., 2009). Getha-Taylor (2007) notes that public crisis management teams are often staffed by people from non-disaster organisations, with different professional backgrounds, and members of disaster organisations. This can create cultural barriers. Her response to this challenge is to build relationships between actors at different levels before a disaster strikes. Therefore, training in soft skills to build relationships and equip managers and key personnel with the necessary flexibility, skills and confidence to deal with sudden and unexpected events (Di Loreto et al., 2013) is an important part of emergency preparedness.

2.2 Serious Games and Mixed Reality

One way to address soft skills training could be the use of serious games. A serious game provides participants with a fun and immersive experience from which they can learn at an individual and group level (Di Loreto et al., 2012). Kankaanranta & Neittaanmäki (2008) define serious games as “games which aim at providing an engaging and self-reinforcing context in which to motivate and educate the players”. Serious games can be a forum for enhanced understanding, training and relation building (Fleming et al., 2020). Serious games can help crisis managers and actors to see things differently (and act differently) from the way they are used to (Di Loreto et al., 2012), and can be a useful tool to bring stakeholders from different backgrounds closer together in a simulated environment (Schueller et al., 2020). Solinska-Nowak et al. (2018) note the social dimensions of serious games: collective play contributes to relationship building, negotiation, conflict resolution, and experience and information sharing, all of which can be useful in disaster preparedness. The same authors also highlight another important aspect. Despite their many advantages, serious games cannot replace more standard approaches to disaster preparedness education. One of the main limitations of games is that they inevitably oversimplify the circumstances of disasters (2018, p. 1026). Therefore, serious games cannot be treated as stand-alone disaster management training tools. Crisis management competence is developed in a series of recurring exercises, rather than in a single exercise (van Laere & Lindblom, 2019). A serious game can provide an arena for social interaction that takes place in the natural context of practice, which can facilitate valuable collaborative skills that can be useful later in a comprehensive capability building process.

One of the key challenges in designing training simulations is how to make them relevant for actual practice (Alharthi et al., 2018). Previous simulators often attempted to replicate the environment as closely as possible,

to improve practicality and immersiveness. However, an exact reproduction of the environment is not always necessary (Jensen et al., 2013). This presents designers with the challenge of striking a balance between capturing the real experience and making the training practical, yet effective (Alharthi et al., 2018). By reducing fidelity, for example by using photos and local maps instead of a virtual reality, the game can be more easily focused on one aspect of training, such as coordination, making the training more suitable for evaluation (2018).

Mixed reality is an alternative way to balance between immersion and reality in training (Alharthi et al., 2018). Mixed reality games engage the surrounding environment through physical interaction with tangible objects, mental engagement with simulated elements, and social interaction with other participants engaged in the same exercise. These types of games can offer unique opportunities to design training simulations that capture the different aspects of crisis management (2018). Mixed reality combines virtual information with physical reality in physical environments. This use places the game in the natural context of practice and can add realism. A serious game consisting of a live, scenario-based mixed reality simulation will allow actors to coordinate with each other, both face-to-face and remotely, to mitigate a simulated disaster (Fischer et al., 2021). These types of serious games also help responders build advanced coordination skills by facilitating training opportunities for human-agent coordination and collaboration (Ramchurn et al., 2016).

2.3 Game Design

2.3.1 Command Post Exercises

One way of distinguishing between exercises is between discussion-based and operations-based exercises. In its doctrine, the U.S. Department of Homeland Security describes “games” as a discussion-based exercise. Games are designed to present an actual or hypothetical situation to ensure that actors make plausible decisions and take appropriate actions. Games can be used to improve operational and tactical skills, stimulate team building or reinforce training (Department of Homeland Security, 2020, pp. 18-19). The same doctrine describes functional exercises as operations-based exercises. Functional exercises are most often designed to evaluate and test functions and capabilities in a realistic, real-time environment, but with a simulated movement of resources (2020, p. 20). A specific type of functional exercise, often called “command post exercise”, deals only with management elements and is carried out by practising the management function within an organisation or in cooperation with other organisations, without using their crews, but by practising cooperation within or across organisations (Sommer et al., 2020).

2.3.2 Design Principles and Possible Pitfalls

Alharthi et al. developed a set of design principles for developing games that engage actors in crisis response style communication, planning and sense-making activities. These principles are listed in Table 1.

Table 1: Game design patterns (Alharthi et al., 2018)

Design Principle	Description
Mix communication	Teams should work in situations in which members spend some periods collocated and others remote, which enforces the need for learning and practising implicit coordination and overhearing.
Distribute information with uncertainty	Different members of the team should have different items of information, requiring team members to share and integrate information and enabling the formation of team cognition constructs.
Enhance situation awareness	Audible clues should supply information about the local situation that is made available to other team members through a shared audio system, engaging team members in processes of developing situation awareness.
Engage developing intelligence	Team members should make informed decisions about how to collect information and need to make judgments concerning its authenticity and value. to identify essential elements of information.
Create emergent objectives	Emergent objectives may be discovered and lost as a scenario of a disaster plays out, and team members may identify new objectives through gathering information.
Support collaborative planning	Team members need to consider converging and diverging lines of activity that take place in the field, in which they should learn how to collaboratively plan for contingencies when activities enter exceptional states.

Van Laere & Lindblom (2019) note that the choice of scenario is of minor importance. Rather, the training design should focus on accurately simulating basic crisis management processes that are relevant in any crisis scenario (e.g. interpreting early signals, alerting and informing the public, situation analysis, creating situational awareness, delegating tasks, and prioritising resources and problems, etc.) (2019, p. 43). They also provide some useful tips in their characterisation of the training approach: (i) crisis management training is an environment to develop and learn, not an examination; (ii) first educate, then train; (iii) focus on “how the crisis management organisation operates,” and not on resolving the scenario; (iv) active coaching during game execution speeds up the learning cycle; (v) encourage self-evaluation; and (vi) recurrent training is needed to master different skills and to refresh collective memory (2019, p. 45).

In an overview of collaborative serious games for crisis management, Di Loreto, Mora and Divitini (2012) comment on possible pitfalls in game design and content. These are: (i) there is limited linkage with an actual territory (i.e. the game takes place in an abstracted environment); (ii) there is virtually no possibility to play with roles (i.e. there is no room for cross-training to gain a deeper understanding of each other’s roles); (iii) the importance of the debriefing phase is underestimated (i.e. there is too little focus on evaluation and knowledge transfer); and (iv) there is no support for coaching during the game sessions (i.e. there are no natural breaks in the game to coach the participants) (2012, p. 5).

These theoretical foundations have guided the design process of the serious game for two-level, collaborative training in crisis management.

3. Method

3.1 Co-design Approach

An iterative co-design process took place, as shown in Figure 1. The literature review and interview session were conducted to adapt the game to *generally accepted principles and design*. The workshop focused more on developing the details of the game content by “brain-picking” people with several years of experience from dealing with different crises at the tactical level. This was all to increase the realism and credibility of the game and, ultimately, its face validity.

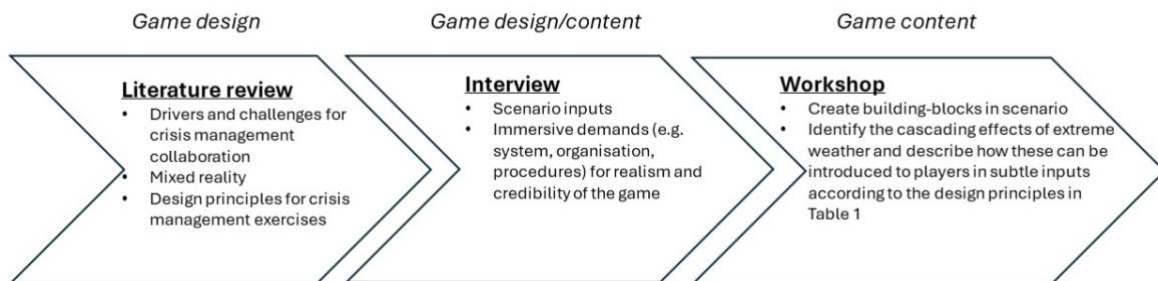


Figure 1: Design and development process

3.2 Interview

To validate the game design principles before developing the content, an expert evaluation was carried out with two experts. These were a high-ranking academic in the field of crisis management, and a person from the Norwegian Directorate for Civil Protection (DSB) with more than 10 years’ experience with exercises at both municipal and county manager level. A semi-structured interview was conducted to increase the relevance of the serious game and to answer the following questions: (i) given the design principles, which scenario is the most useful to include in order to involve several communities and simultaneously challenge the county management level?; and (ii) which prerequisites should be included in order to make the mixed reality relevant and realistic?

3.3 Workshop

The workshop was attended by eight participants representing the emergency services, all with between 11 and 20 years’ experience. The services represented were the police (2), fire brigade, ambulance service, Red Cross, Norwegian Public Roads Administration, army, and Home Guard. All workshop participants attended the BA course in “Emergency Training and Exercises” as part of the final semester of their bachelor’s degree in Crisis

Management. All participants had experience with crisis management software and knowledge of basic exercise planning. The aim of the workshop was to detail the lead-in scenario and storyline, and to generate ideas for cross-sector playable scenario inputs and cascading effects of extreme weather that would trigger or include the elements from Table 1 (Alharthi et al., 2018). The workshop lasted just over two hours and was divided into 15-minute sessions, with each session focusing on a different element from Table 1. The group work was followed by a 30-minute summary session to refine the ideas.

4. Results and Discussion

4.1 Expert Interview

During the expert interview, a few scenarios which could give rise to “downstream consequences” were discussed. These included a failure in a nuclear reactor and a municipal data hack. However, both responders asserted that the most suitable scenario for this game’s intention would be an extreme weather scenario. This scenario is highly relevant as it encompasses a multitude of potential cascading effects. Cascading effects in public crisis management occur when an incident triggers a series of interconnected events, such as floods, waterborne infections, loss of electricity, landslides, and so forth. These effects could unfold in a disparate manner across the municipalities, ultimately creating significant challenges for the county manager’s office.

Mixed reality games engage the surrounding environment through physical interaction with tangible objects, mental engagement with simulated elements, and social interaction with other participants engaged in the same exercise (Alharthi et al., 2018). The experts identified a select number of universal, cross-sectorial objects that could be used in such a game, to facilitate a realistic mixed reality. The crisis management software, which is available to all municipalities and county managers’ offices in Norway, facilitates crisis management at all levels by enabling the logging, reporting and sharing of analyses and information. The “Proactive Staff methodology” (Lunde, 2019) entails the establishment of a fixed meeting agenda and subsequent reporting for all levels of staff. The methodology facilitates crisis management in the initial phase, enabling the effective resolution of problems that may arise. The methodology indicates that a startup meeting is of paramount importance, during which a common situational picture is established, based on the facts at hand, and the consequence potential is assessed. This potential serves as a basis for decision and allows decisions to be taken now, based on an analytical assessment of the future. The utilisation of maps, map layers and “aerial photos” extracted from VR was recommended as a means of enhancing the scenario. This low-fidelity use of simulators does not detract from the focus on the task at hand. In terms of social interaction, the respondents proposed the convening of separate meetings in the municipalities and county offices, with a subsequent cooperation meeting with one representative (liaison officer) from each of the municipalities. This approach would facilitate the socialisation of both levels within and across crisis management levels. These inputs were instrumental in the further design of the game. At the end of the interview session, a game organisation was proposed, as shown in Figure 2.

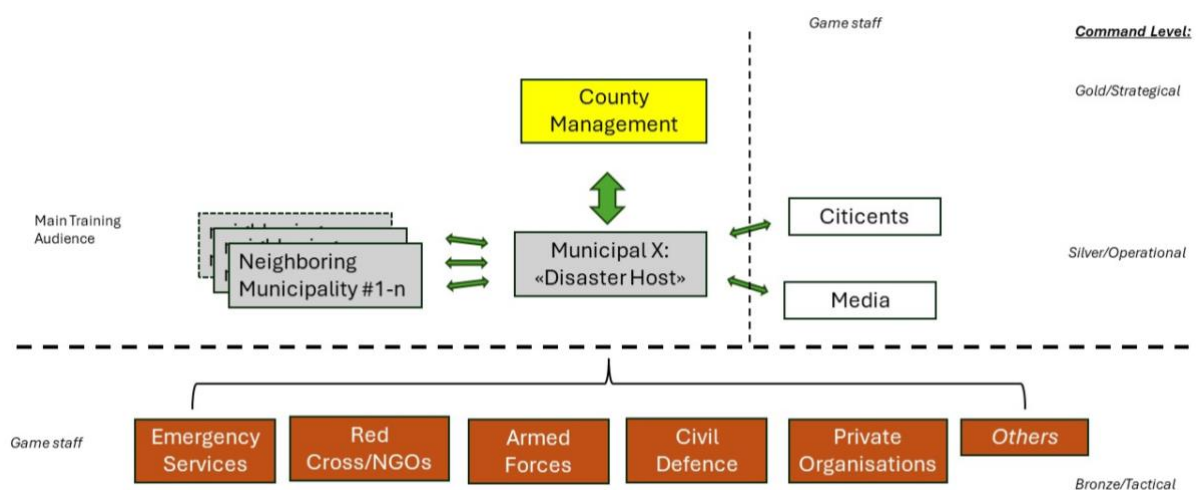


Figure 2: Game organisation

4.2 Workshop

The workshop focused on the creation of concrete game content, such as lead-in scenario and storyline details, ideas for cross-sector playable scenario inputs, and relevant cascading effects of extreme weather. The group work was framed by the results of the expert interview: focus on the challenges of collaboration at two levels of command, extreme weather scenario, use of crisis management software and a standardised staff methodology. With these assumptions in mind, workshop participants used the patterns from Table 1 as guidelines for the creative process of developing ideas for game content.

4.2.1 Mix Communication Modalities

There was a substantial degree of consensus regarding an approach to organising the players to achieve this objective. Firstly, all participants are gathered in one room to have a common briefing, where all common information is shared (step 1 in Figure 3). Then each municipality goes into separate “command posts” to prepare and execute their internal startup staff meeting (steps 2-3). After 45 minutes, they send a meeting report to the county manager’s office (step 3a). Subsequently, they commence preparations for the forthcoming startup meeting, which is primarily based on the in-brief and the reports from the municipalities (steps 4-5). After the county manager’s office has delivered their meeting report (to the game staff, step 5a), a physical cooperation meeting is held with a representative (liaison officer) from each municipality (step 6). This meeting is open to all game participants for educational purposes, although only those present at the meeting will actively participate. Here final warnings, actions and supports are planned to achieve a unified effort (step 6a).

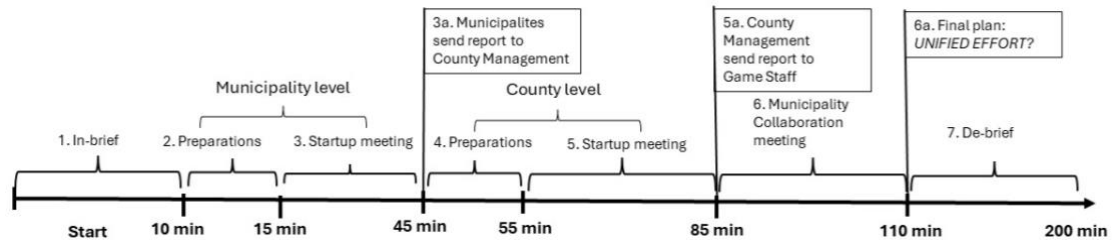


Figure 3: Game timeline

4.2.2 Distribute Information With Uncertainty

The workshop resulted in the formulation of a concrete scenario pertaining to extreme weather conditions. The lead-in scenario is set in an extreme hot and dry summer. A municipality experiences the outbreak of a forest fire near two neighbouring municipalities, yet there is no control of the fire. The weather forecast predicts two days of high temperatures, followed by heavy rainfall and thunderstorms. The wind will change direction, turning 180 degrees. The lead-in scenario itself entails the potential for several cascading effects of the heatwave, including the possibility of more wildfires, the evacuation of citizens, the closure of roads and railways, the loss of electricity, and torrential rain with potential landslides and thunderstorms. This information, along with regional maps and a brief overview of resources, is presented in a neutral manner. Following the introductory briefing, the various player groups proceed to their designated “command posts” to prepare for their initial meeting. It is up to the players to identify the potential consequences of incidents affecting their region, considering the specific characteristics of the municipality in question.

4.2.3 Enhance Situation Awareness/Engage Developing Intelligence

Crisis management software enables the sharing of images, including tailored “news articles” from both regional and national media sources. The workshop yielded several ideas, including articles on the impact of extreme weather events, alongside information on the indirect effects of such events. One example is an article on local actors who are looking forward to the implementation of a major public event (which geographically will be very exposed to the wildfire, if the wind turns). Furthermore, information shared via crisis management software may comprise a combination of data extracted from social media, which may include both useful information and irrelevant content. It is therefore necessary to verify the accuracy of this information.

4.2.4 Create Emergent Objectives

The relevance of different cascading effects to different municipalities may be contingent upon geographical, technical and demographic differences. The workshop focused on the identification of incidents that could potentially occur within a municipality, with the understanding that the consequences might extend beyond the immediate area. This included an examination of the potential impact of such incidents on neighbouring municipalities. To be able to handle these incidents, it is necessary to provide advance warning to the relevant region, so that it can take timely action. Examples of such incidents include the issuing of warnings concerning the imminent closure of roads and railways, the potential loss of electricity or drinking water, and the risk of waterborne infection.

4.2.5 Support Collaborative Planning

This part of the workshop focused on the identification of cross-municipal factors that could potentially have an adverse effect on regional critical infrastructure. One such factor was the potential impact on a regional hospital. The objective of converging and diverging lines of activity may also be incorporated into the lead-in scenario, in which different municipalities require assistance from one another in order to effectively address the potential cascading effects. At the individual startup meeting (steps 2-3 in Figure 3), the municipality *can* ascertain the necessity of notifying neighbours and identify its own need for support. This requires both skills and cleverness. Consequently, the period following the municipalities' start-up meetings (after step 3a) is deemed an opportune moment in the game for the delivery of coaching to the staff. Furthermore, the game offers a second opportunity to identify instances of convergence and divergence in activity. At the municipal collaboration meeting (step 6), participants are expected to consider the region as a unified entity and to identify actions that can be undertaken collectively. At this stage, all the players rally behind a plan, a *unified effort*.

4.2.6 Game Mechanics

The chosen methodology, software and meeting structure provide direct guidance for the mechanics of the game. The in-brief reveals some details of the scenario and sets the scene. This is a standard brief given to all players simultaneously, using a fictional narrative provided by pictures and maps. The purpose of this introduction is to answer the "who", "where", "when" and to some extent "what"- questions. After the joint briefing, all participants go to their individual locations, each of which is equipped with a monitor and the crisis management software. The crisis management software menus displayed on the monitor represent the user interface elements. Incoming messages are displayed in the log stream and outgoing communications are sent and displayed in the message distribution menu.

The Proactive Staff methodology dictates that you always begin with a startup meeting with a fixed agenda, which implies six questions: (i) what happened, what do we know?; (ii) what are the potential consequences?; (iii) what do we do?; (iv) what do we need?; (v) what are the consequences for daily operations?; and (vi) are there other issues working for or against us? After the various crisis teams have held their initial meeting, they distribute their meeting report in a standardised format to all participants using the crisis management software. The teams will receive updates and inputs, both fake and real news, through this channel during the game.

The meeting structure, with two common arenas (in-brief and coordination meeting) and one individual meeting, forces the crisis staff to make timely decisions and fill in the agenda items of the start-up meeting. The output of the individual staff meetings, received in the crisis management software, will provide important input to neighbouring municipalities and the county managers' office.

The entire game is outlined in Figure 4.

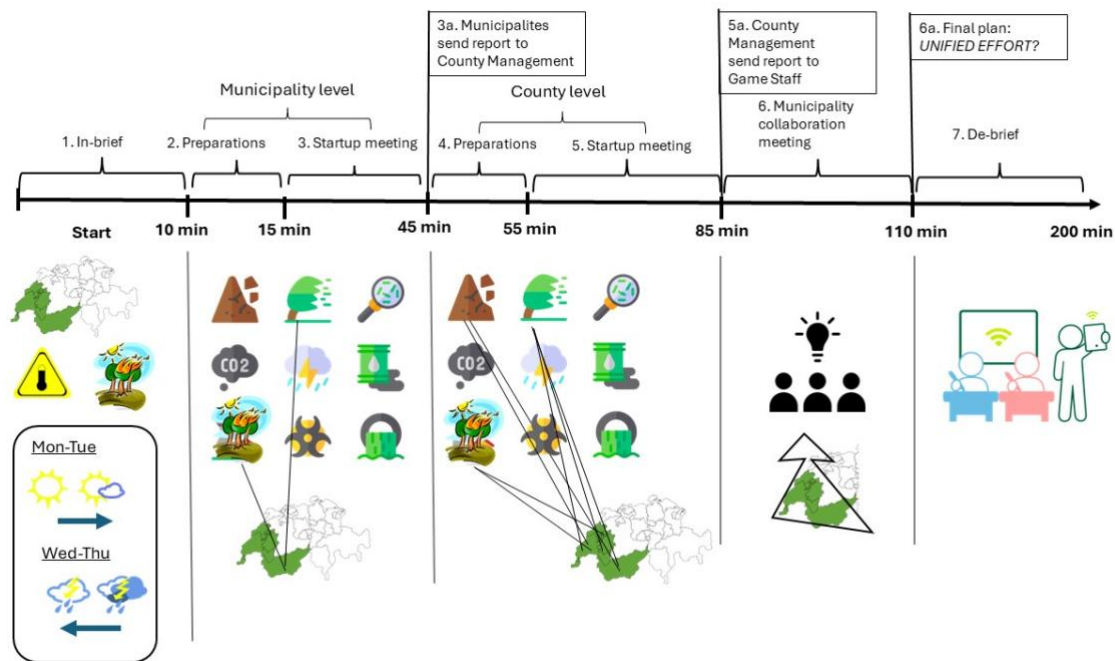


Figure 4: Principal sketch: "United Effort" (Images collected at www.seekpng.com)

4.2.7 Limitations and Further Research

A limitation of the game is that it requires a certain level of competence in staff organisation and decision making. It also requires some knowledge of communication and information sharing. Therefore, inexperienced staff will need some basic training in advance. It is recommended that participants attend a half-day seminar on the Proactive Staff methodology to familiar themselves with the meeting agenda and the expected outcome of the startup meeting. Some basic knowledge is also required to use the crisis management software. The supplier of the software will provide its own training, and it is important that at least one member of the staff is an experienced user. Alternatively, this role can be filled by a member of the game staff to ensure a smooth flow of information and log-keeping.

The next step is to pilot test the exercise in its entirety. This will be the subject of the next study. Effective staff work is the result of a complex mix of condition factors (personnel, organisation and context), process factors (team- and task-focused) and outcome criteria (Essens et al., 2005). After the pilot test, a qualitative study will determine the actual experience of the players in order to improve the *condition factors* and make the game more realistic. Through a semi-structured interview, pilot test participants will be asked to share their experiences of the game and suggest improvements. Topics of the interview will be perceived realism and the balance between size (duration of the game, number of participants) and complexity (how many factors are included and how realistic are they?).

The game will then be used in training sessions where different questionnaires will be used to quantitatively measure more specific learning objectives related to the different soft skills (*process factors*). Different metrics will be used to evaluate the impact of the game on participants' skills and ability to collaborate. Berlin & Carlström's survey instrument will be used to measure collaboration, perceived learning and utility (2015, p. 23). Barton et al. (2015) has shown that "anomalizing" and "proactive leader sensemaking" play crucial roles in determining success for operational teams. They provide survey items for both factors (2015, p. 83). These measures will be supplied by more general psychological terms of collaborative importance, such as self-efficacy, social support and interaction (Herberg et al., 2018). The game itself provides measurable *outcome criteria*, such as group decision making (on time and content quality). (Shared) situational awareness will be measured (Endsley, 1995) and communication logged to capture whether, for example, cascading effects relevant to other participants are registered and communicated to the right actors.

The game is designed for Norwegian municipalities and county councils. This may limit its generalisability to other contexts. However, the game is designed to focus on training general soft skills and how the crisis management organisation works, communicates and cooperates - not on solving the scenario. The design

principles of this game can be applied to any scenario involving two levels of crisis responders. The cores are the meeting points, the dissemination of the decisions of the different participants to the other players and the correct use of this information to build a common situational awareness. Different versions of the United Effort game therefore have the potential to train any two-level crisis management, but with an adapted scenario and communication network.

5. Conclusion

This paper proposes a short serious game for collaborative training with two levels of command in a mixed reality. The game is designed for basic training of municipalities and county offices in soft skills. The “Unified Effort” game addresses the need for forums where different community safety stakeholders can learn from each other and provides a “missing link” in a sequence of exercises. Collaborative skills are usually learning objectives in full-scale exercises, but the “Unified Effort” game allows responders to train these skills on a smaller scale and early in the training process. Serious games are not intended to replace hard skills training such as procedural training and field exercises, but they can be used to complement this type of training. Both soft skills and hard skills exercises have their natural place in a progressive, comprehensive capability building process.

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