Adopting a Trading Zone Framework to Emergency Management

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Abstract

This paper presents a novel framework for identifying and detailing the processes of Information Trading Zones in Emergency Management. Drawing inspiration from various scientific disciplines, we demonstrate the applicability of these insights within Emergency Management in the Information Systems domain through a detailed case study. By leveraging these adapted concepts, our framework enhances understanding of information exchange and collaboration in emergency response efforts. Through this research, we shed light on the relevance and effectiveness of the framework in addressing the unique and dynamic challenges of Information Management in Emergency Management scenarios.

Keywords: trading zone, emergency management, situational awareness

1. Introduction

In real-world crisis scenarios and emergency exercises, the collaboration between stakeholders and organisations depends on Information Systems (IS) that secure effective communication, information sharing and acquisition. Analysing the effectiveness of IS in Emergency Management (EM) can be difficult due to the dynamic nature of some incidents handled by EM, characterised by rapid onset, chaotic environment, and challenges related to collaborative evaluations post-incident (Radianti et al., 2023). We suggest a novel approach to this challenge by introducing a framework for identifying the characteristics of Trading Zones (TZ) in EM, and we seek to adapt ideas from physics, social and cultural studies to IS in EM settings. Although the TZ concept has helped capture the process where EM actors exchange and negotiate information with each other, there is limited literature on the detailed process concerning what processes happen in TZs and how this relates to the EM context. Thus, this research aims to understand TZs better, explore the characteristics of TZs, and propose a theoretical framework that can explain such a process. We refine the concept of Information TZs through a thorough literature review and present an extended framework developed during a collaborative workshop with participants from industry and academia. We then showcase its practical application by analysing a full-scale exercise. We argue that the novel framework offers a promising approach when analysing past events demanding collaboration and information sharing in EM. We also see that it can be beneficial when doing risk assessments and planning for future incidents.

Our research question is: *How can we adapt a framework for Trading Zones from social studies to Information Systems in Emergency Management?*

The proposed TZ framework was derived from a Forest Fire Exercise in Norway (April 2023) and a workshop with experts in EM (May 2023). Since the organisation of EM varies across nations, our references to experience concerning the TZ framework will relate to the Norwegian levels of organization (Figure 1). Understanding the EM organisation structure is essential, and Information TZs can occur vertically and horizontally. This paper's novelty is proposing an adapted Information TZ Framework for EM and detailing the processes occurring within Information TZs. In Vertical Information Trading Zones, information negotiation and trading happen across the organisational levels. In Horizontal Information TZs, information negotiation and trading occur within the organization (Rimstad et al., 2014)

This paper is organised as follows. First, we motivate the need for research on information TZs in EM through a literature review. Then, we present our methodology, data collection, analysis, and results before a discussion and conclusion.

2. Literature Review

The phrases of information trading and negotiation are well known in EM and IS (Boersma

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et al., 2012; Munkvold et al., 2019; Steen-Tveit, 2022). The metaphor of the *"Trading Zone"* was introduced to the social studies of science by Peter Galison in 1997 when he attempted to resolve the problem of incommensurability between Kuhnian paradigms (Collins et al., 2007; Galison, 1997). He saw scientific paradigms not as monolithic in a Khunian way but as overlapping. If the logic of monolithic paradigms was true and followed to its full extent, there should be no overlapping between paradigms and, hence, no communication. But the emergence of disciplines like Information Systems (IS) proves this wrong. IS is multidisciplinary by nature, and at the core, it arose out of Computer science and Management science with the diffusion of language, pieces of devices, and fragments of theories connecting groups of practitioners despite disagreeing about their global significance (Khazanchi & Munkvold, 2000). The overlapping zone where this diffusion occurs is called a Trading Zone by Galison (Galison, 1997)

Figure 1. Levels of EM Organisation in Norway (Rimstad et al., 2014).

2.1. A General Model of Trading Zones

Collins et al. introduce a general model of TZs and demonstrate how it can be used to describe the evolution of a new scientific discipline. They define TZs as locations in which communities with deep communication problems manage to communicate. According to their definition, not all trade is conducted in TZs (Collins et al., 2007). Their general TZ model considers two dimensions along which TZs can vary. One dimension is the coercion-collaboration axis, which visualizes the extent of power used to enforce information trading. The other dimension is between homogeneity and heterogeneity and shows the extent to which trade leads to a homogenous new culture (Collins et al., 2007). The two axes lead to four basic types of TZs, as seen in Figure 2.

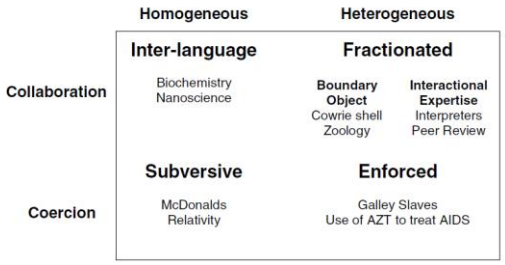

Figure 2. A General Model of Trading Zones (Collins et al., 2007).

A TZ characterised by heterogeneity and a high degree of coercion, as is demonstrated in the lower right corner of the quadrant. This zone would have low cultural sharing, and one party would dominate the other. In the fractionated TZ on the top right corner of the quadrant, multiple cultures collaborate, and fractions of cultures are the medium of interchange.

Furthermore, Collins et al. propose two kinds of fractioned TZs: *boundary object TZs* and *interactional expertise TZs.* A *boundary object* may mean different things to the different parties, but it does not vitiate their separate projects (Star, 1989; Star & Griesemer, 1989). Boundary objects can be both physical and intellectual constructions that join people together in collaboration. Examples of boundary objects could be a common goal-oriented project or a map-based collaboration system. *The Interactional expertise TZ* is able to function due to members of the collaboration learning the language of others and shifting back and forth between different social and cultural worlds (Collins & Evans, 2002).

In the upper left corner of Figure 2, the Inter-language TZ is characterised by a high degree of collaboration and a common linguistic community, where the different members are able to communicate and collaborate through either pidgin or jargon or a full-blown creole language. We argue that the TZs of Interactional Expertise and Inter-language correlate with Team SA Mechanisms and shared mental models (SMM) (Endsley & Jones, 2001). In the Subversive TZ found in the lower left quadrant, one party`s language overwhelms the others. One example of this could be a CBRNE incident, where expert knowledge of the threat related to the incident's potential will be dominant over the police´s need to investigate (Collins et al., 2007). Based on Collins et al. (2007), TZs are classified as seen in Table 1.

Table 1. Classification of Trading Zones (Collins et al., 2007).

Classification	Characteristics
Inter-language Trading Zone	High collaboration, high homogeneity
Subversive Trading Zone	High coercion, high homogeneity
Enforced Trading Zone	High coercion, high heterogeneity
Fractionated Trading Zone	High collaboration, high heterogeneity

2.2. Trading Zones and expertise

Michael E. Gorman (Gorman, 2002) suggests that there is a link between levels of expertise and three kinds of TZs (Table 2).

Table 2. Relationship between Expertise and Trading Zones (Gorman, 2002).

Trading Zone:	Elite	Boundary Object	Shared representation
Expertise:	None	Interactive	Contributory

In the Elite TZ, a group of experts will control a network where there is really no trade of information. The experts will use their specialised knowledge to dominate the TZ or threaten to exit. Their expertise is black-boxed for other participants in the network, and access to knowledge is tightly controlled. This TZ relates to the Enforced TZ in Collins et al.'s framework (Figure 2).In the second TZ, *a Boundary object* (Star, 1989; Star & Griesemer, 1989) leads the experts into collaboration and interactivity. *In the Shared Representation TZ*, there is a common understanding of goals, experts engage more deeply, and they are able to contribute jointly to reach a common goal (Gorman, 2002).

2.3. Trading Zones and Common Operational Picture (COP)

In previous studies, the metaphorical use of TZs has been used and is often mentioned in relation to a Common Operational Picture (COP) (Steen-Tveit, 2022; Wolbers & Boersma, 2013). A COP can be defined as a selection of available information units (Borglund & Granholm, 2020) or as a "centralised information display system" (Hwang & Yoon, 2020), presenting situational and operational information from various sources relevant to the involved stakeholders" (Steen-Tveit & Munkvold, 2021). In this perspective, TZs are necessary as they enable negotiation for developing collective sensemaking of information from a COP (Wolbers & Boersma, 2013). Boersma and Wolbers´s comprehension of a TZ is drawn upon two leading yet opposing doctrines in crisis governance. *In the first doctrine*, a crisis is understood as creating chaos. The institutional design in this doctrine is paramilitary, top-down and based on the military analogy that disasters are the enemy and must be approached as such. Formal response organisations often struggle with coordination in decision-making and getting their operational picture right due to the situation's complexity. Command and control are required to normalise crisis situations, and it is important to establish a chain of command to ensure that stakeholders know "who is in charge". In this perspective, information should be available for all actors all the time. The metaphor for an optimal information system is a *warehouse* where a perfect COP mirrors the actual situation and lets the individual actors select the information that is appropriate for them to perform their tasks. The hunt for an ideal COP as a solution for information exchange can lead to a focus on creating the perfect COP rather than the ongoing process of information sharing that the crisis demands (Boersma & Wolbers, 2021). The top-down design and chain of command make adopting and including spontaneous volunteers and local communities challenging as they are not formally trained. *The second doctrine* builds on the idea of continuity and represents a crisis or a disaster not as chaos as a solid state but rather as a cause of a certain degree of unrest (Boersma & Wolbers, 2021; Solnit, 2010). Behaviours in a crisis do not change much, panic and turmoil do not emerge on a grand scale and social structures are often not compromised. In this perspective, collaboration and coordination are key. Not control. Crisis information can be imperfect, incomplete, contractionary, and ambiguous. Therefore, the focus is on solving the problems at hand, not creating the perfect COP or controlling chaos. Comfort (2009) argues that a COP needs to create a sufficient level of information among the different stakeholders so that they understand the constraints and possible combinations of collaboration and support they have at hand during the crisis (Comfort, 2007), which is in line with Endsley´s definition of Team Situational Awareness (TSA) (Endsley, 2020). Boersma and Wolbers argue that COPs can be seen as both a part of and outcome of TZs, where information is shared, given meaning, and talked about. The differences between the two doctrines can be pictured in a dichotomy of Information Warehouse and Trading Zone depicted in Table 3.

Table 3. Crisis Information Management within the Two Doctrines (Boersma & Wolbers, 2021).

Information Warehouse	Trading Zone
Transfer of information	Translation of information
Univocal	Multiplicity
Static (packages)	Flux (processes)
Accessible	Negotiation
Clarity	Equivocality
Self-synchronisation	Collective sensemaking

Using the TZ perspective to design a COP means that the COP is part of a collective sensemaking and negotiation process, which is difficult to achieve in a more top-down, hierarchical command and control system (Boersma et al., 2014). TZs cannot be reduced to just spaces where information is negotiated and traded, we also have to recognise that collective sensemaking is multi-dimensional. One key feature of EM settings is that the underlying collective sensemaking occurs in different organisations that are temporarily dependent on each other. From this, Boersma and Wolbers argue that four TZ Dimensions (TZD) are to be considered: Cognitive, Social, Cultural and Political (Boersma et al., 2014). Table 4 shows how the TZDs relate to Processes, Drivers, and Lessons from Research.

Table 4. Trading Zone Dimensions (TZD) (Boersma & Wolbers, 2021).

TZD	Processes	Drivers	Lessons from Research
Cognitive	Sense-making and sense-giving	Enactment and plausibility	Actors must make sense of information based on training and experiences
Social	Partnering and networking	Swift trust	Actors collaborate based on trust developed in direct performance
Cultural	Narrating and storytelling	Epistemic cultures	Actors express their values and sensemaking through storytelling
Political	Legitimate and agenda-setting	Power and discursive practice	Information is used for framing and negotiating of interests

3. Methodology

This study is designed as qualitative research. The empirical foundation of this article was drawn from two sources: participatory observations from a full-scale forest fire drill and an exploratory workshop with EM experts.

3.1. Forest Fire Exercise

In April 2023, the main author had the opportunity to participate as an observer in a comprehensive full-scale forest fire exercise. This exercise was organised as a collaborative effort between several organisations, including Norway's second largest fire and rescue service, the fire emergency dispatch centre, the Norwegian Directorate for Civil Protection (DSB), two municipalities, the Norwegian Civil Defence, the Red Cross, and the police. A total of 120 participants from these organisations contributed to the exercise. The primary objective of this full-day exercise was to enhance collaboration and coordination among Incident Commanders (IC) and staff members at a Tactical level (Figure 1) in dealing with a forest fire in a challenging location. The exercise also aimed to promote effective information sharing and explore the utilisation of new technologies, such as unmanned aerial vehicles (UAVs) and on-scene video transmission, within the operational and strategic levels of response (Figure 1). By engaging in this exercise, participants had the opportunity to refine their skills, test their response strategies, and address the complexities associated with managing a forest fire. The exercise provided a realistic environment where ICs and staff could practice decision-making, communication, and the utilisation of advanced technologies. We were allowed to take photos and record video in agreement with the IC from the fire and rescue service. We were also allowed to speak freely with the different participants as long as this did not interfere with them participating in the actual exercise. During the exercise, three researchers, including the first author, were involved (Table 5).

Table 5. Distribution of researchers.

Researchers	Situated	Level (s)
Res 1	In the Fire Emergency Dispatch Central. Separate location.	Strategic/ operational
Res 2	On scene with forwarded command and control vehicle	Tactical/ operational
Res 3	On the scene with incident commanders from fire-rescue, police, Red-cross and The Norwegian Civil Defense	Tactical

In advance of the exercise, we had meetings with the management, instructors and training officers from the fire and rescue services. We were introduced to training protocols and exercise goals and were given observer roles at both Tactical, Operational, and Strategic levels (See Table 5). Afterwards, we were given access to evaluation

reports, timelines and audio logs. We also had a session together with the facilitators of the exercise, where we, as researchers, shared our observations. EM responders in Norway use the Norwegian Public Safety Network (NPSN). The NPSN is a closed and secure radio network. Outtakes from audio logs that were retrieved from six active NPSN channels were transcribed and coded from relevance in different TZs. In total, 60 minutes of audio logs were transcribed and analysed. The exercise was initiated at approximately 06:00 a.m. by public reports of observation of white smoke from a remote forest location. This triggered a moderate response from the local fire department, sending out resources to validate initial reports. By 07:00 a.m., the local fire officers on the site reported heavy smoke from an unknown location in the forest, and by 08:00 a.m., a large response from multiple organisations was initiated to collaborate in controlling the fire. The exercise lasted until 5:30 p.m. and was wrapped up with a semi-formal quick evaluation (Hotwash) on site.

3.2. Workshop with EM Experts

During a large EM conference in 2023, we organised a workshop as part of the pre-conference activities. The workshop aimed to explore the significance and impact of information TZs in the context of IS for EM and validate the relevance of our insights from a literature review. Our goal was to facilitate knowledge sharing and gather insights from the participants. The workshop spanned three and a half hours and involved nine EM experts. It was designed to be interactive and engaging. During the workshop, interactivity was enabled using SLIDO (Slido.com) as a PowerPoint add-on. We started the session by asking the participants about their background and to share the first word that springs to mind when hearing the phrase *Trading Zone*. From this, we created a word cloud emphasising the most frequent word: Negotiation. We then discussed if insights presented from the literature review could be relevant to EM and what the characteristics of TZs in EM would be. The participants were introduced to the Collins et al. framework (Figure 2). They had breakout sessions where they were challenged to apply the framework and identify possible TZs on a fictive case study involving a passenger airplane crash in a remote location and a forest fire as a secondary consequence. Findings from the breakout sessions were then discussed in plenary. Finally, we discussed relevance and modifications to the Collins et al. framework to make it more appropriate for EM.

4. Results

In this section, we present the results from both the workshop and the Forest Fire Exercise.

4.1. Toward a Trading Zone Framework in EM

From the workshop (3.2), we derived a preliminary revised framework. The workshop participants built a consensus that the use of the TZ-metaphor in EM is appropriate. They agreed that the Collins et al. framework was suitable but needed adaptation to have relevance in EM. The authors and the workshop participants agree that the terms Enforced, Fractionated, Inter-language and Subversive TZs are relevant in an EM context and correlate with their respective axes, but the term Inter-language is not well known in EM. To make it clearer, we adopt Gorman's Shared Representation TZ and argue that this is also recognized by high collaboration and high homogeneity (Table 2). By adjusting the framework, it could be useful both for analysing past events that demand collaboration and when doing risk assessments. One finding was that the link between the framework and intrinsic and extrinsic motivation was not clear, even though Collins et al. argue that motivation and compliance can be problematic in the Enforced TZ (Figure 2) (Collins et al., 2007). It was first argued that this belonged to a separate axis, making the model three-dimensional. Although visually appealing, this generated a problem since it would create new, irrelevant TZs, such as a Subversive, intrinsically motivated homogenous TZ. The authors decided to keep a two-dimensional model and give motivation a place where it would be a prerequisite for information trading to take place. Crisis and emergencies often inspire people to volunteer and get involved for various reasons, like a sense of community, responsibility, individual values, and self-identity (Yang, 2021). While intrinsic motivation can sometimes resemble coercion, we consider it a separate concept (see Figure 3, 1). Volunteers can be divided into two distinct groups: traditional volunteers, like those in organisations such as the Red Cross, who follow regulations and protocols and may experience varying degrees of coercion or external influence, and autonomous digital volunteers, who act solely on their intrinsic motivation, operating independently without external regulations. There's a voluntary aspect in civil protection, but the organisational structure resembles a military hierarchy, common in traditional volunteer organisations and civil protection agencies. The

interplay between voluntary and coerced participation can be intricate. For instance, volunteers might find themselves in situations with varying levels of coercion or external pressure, leading to complex interactions with professional actors, resulting in challenges and tensions. Language can pose a significant challenge in these contexts and thus create the need for either an ICT-supported boundary object, like a digital map or common radio network (Figure 3, 3a) or interactional expertise for effective information exchange to occur (Figure 3, 3b). Interactional expertise can be gained by volunteers co-training in advance, creating Shared Mental Models (SMM) with professional actors, thus supporting TSA in case of a real crisis (Endsley & Jones, 2001). Also, a relation between a COP and the Trading Zone is not clear in either Collins or Gorman's frameworks. We argue that there is a dynamic relation between a COP and Information TZs. For a COP to be accessible to all actors, it must transcend through a Boundary object (Figure 3, 3a). Data and information units from the collaboration are generated in one of the other TZs and made accessible through the same Boundary object. In our framework, this is illustrated by a bent arrow crossing the Subversive- and Shared Representation, ending in the Fractionated TZ.

In a contingency perspective (Boersma & Wolbers, 2021; Solnit, 2010), incorporating spontaneous volunteers and local communities would be a vital part of the crisis response. In our adoption of Collins et al.`s framework, we have added a dimension where a dichotomy of Intrinsic and External motivation identifies stakeholders' motivation for entering Information TZs (Figure 3, 1). In the represented new framework, we have also added a loop between *New knowledge* (Figure 3, 5) and *Operationalizing of learning outcome* (Figure 3, 6), where *New knowledge* belongs in the *Subversive TZ*, as knowledge by definition requires some change in behavior or perception, making some understandings subversive over others. This correlates well with the Political TZD (Table 4), where the drivers of Information Trading are power and discourse and information are used for framing and negotiating interests (Boersma & Wolbers, 2021). *The Operationalizing of learning outcomes*, because of new knowledge emerging from the information Trading, we have placed in the *Enforced TZ*. We argue that operationalising learning outcomes from real incidents or exercises implies that actors, when faced with similar incidents in the future, will act in a way that differs from the way they acted previously. This understanding resonates with organizational theories of double or triple loop learning where organizations can reflect and learn from incidents and exercises (Argyris, 1977; Pilemalm et al., 2021; Radianti et al., 2023). This, in turn, can influence the SOPs in use (Figure 4, 2) and further contribute to Interactional expertise (Figure 3, 3a). From this we have derived a novel approach, and an exploratory framework for identifying TZs in EM from an IS perspective (Figure 3).

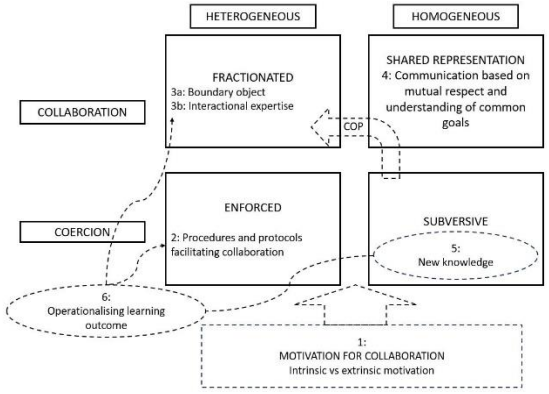

Figure 3. Novel Framework for evolution of Trading Zones in EM.

4.2. Analysis of Forest Fire Exercise by use of the Trading Zone Framework

To understand how our TZ framework can be applied, we must first recognize the dynamics of information TZs. In our analysis we relate the framework to time and to the different phases of the disaster management life cycle: mitigation, preparedness, response, and recovery-phase (Coppola, 2006). The format of this paper does not allow a complete analysis of the exercise, but examples are provided to demonstrate its applicability.

4.2.1. Response phase. In the exercise, the fire and rescue services initiated collaboration on an operational level, first receiving information about smoke detected in the terrain and then alerting collaborative agencies by using and supporting a triple alert standard operating procedure (SOP). The use of SOPs that facilitate collaboration between different agencies that are not used to collaborate under peaceful circumstances, commits the different parties and can aid the individual actor in what may, what must and what must not be shared in a TZ (Figure 3, 2) (Curnin et al., 2015; Phillips-Wren & Adya, 2020) In a Norwegian context, the Triple alert routine between rescue services, fire department, police department and ambulance services is an example of such a procedure. The execution of the

SOP is scenario-based and ensures that all actors get the same information quickly in events where time is sparse. The overall goal of the SOP is collaboration and coordination of resources. Information trading and negotiation at this stage we identify as happening in an Enforced TZ, but the SOPs can be seen both as boundary objects and as strengthening Interactional Expertise, as it supports the collaborative efforts use of SMM. Information initially retrieved by the different agencies led to alarms and responses from the tactical levels via the NPSN. Using the NPSN is mandatory for organised rescue services, thus creating a mandated environment with strong coercion in using IS (Sørebø & Eikebrokk, 2008). Stakeholders were responsible for alarming their resources, but one common radio channel was allocated for collaboration between responding agencies. Trading and negotiation of information in this setting can be recognised as enforced, where established routines secure collaboration between multiple agencies, but with strong coercion (Figure 3, 2), and the key is sensemaking in the initial phase of the incident (Weick, 1993; Wolbers, 2022; Wolbers & Boersma, 2013). But the NPSN also serves as a boundary object, where responders negotiate their understandings and interpretations of information via IS equally available to all, leading collaboration into a Shared Representation TZ. Information trading in this phase resonates with the Cognitive TZD, where actors must make sense of information based on training and experience (Table 4) (Boersma & Wolbers, 2021). While on their way to the scene, the responding units used the shared radio channel and negotiated information to achieve common situational awareness and build a COP. When all the organisations arrived at the scene, they established an Incident Commander Communication Point (ICCP) near the fire. Roles in an ICCP are predefined and follow protocol but are also subject to interpersonal skills and culture. When the ICs from the different organisations teamed up, we observed behaviours reflecting Swift Trust (McLaren & Loosemore, 2019; Meyerson et al., 1996; Wolbers et al., 2017) where the actors would greet each other in a friendly manner, shake hands, smile, and behave respectively—turn-taking when talking was practised, although the IC from the fire and rescue (ICF) dominated. Roles were evident because the ICs wore vests with professional markings and *leader* written on their backs. This resonates with the social TZD, as argued by Boersma and Wolbers (2021), see Table 4.

4.2.2. Back to a Fractionated TZ. As the exercise progressed, information sharing, and acquisition increased in complexity. The collaboration on site started at 9 a.m., and at 10 a.m., we observed at least ten active NPSN radio channels and very little activity in the allocated common channel. Each IC had two radio units, with one earplug in each ear. The NPSN, by this, lost some applicability as a boundary object, and the virtual information flow got fragmented. This led the responders into a Fragmented Information Trap, where there was a discrepancy between the actual-world situation, as communicated by the personnel working closer to the fire sight, and the IC's perceived real-world situation. This can result in inaccurate action due to them receiving incomplete information about the situation (Rustenberg et al., 2023). From this observation, we argue that information trading returned to the Fractionated TZ (Figure 3, 3a), and the organisations worked parallel on separate projects without the benefits of a well-functioning boundary object leading them to a Shared Representation TZ.

4.2.3. Lack of Interoperability. In the exercise, several map-based tools were used by the responders. This was problematic due to their lack of interoperability, challenging their role as boundary objects. Extensive literature on IS for EM has been published, where this is problematised (Borglund & Granholm, 2020; Luokkala & Virrantaus, 2014; Munkvold et al., 2019b; Pilemalm et al., 2022; Steen-Tveit, 2020; Wolbers & Boersma, 2013). Turoff et al. (2006), as an example, provides a comprehensive framework for the design and development of a "Dynamic Emergency Response Management Information System" (DERMIS). The authors offer general design principles and specifications to meet the communication and information requirements of both first responders and command and control personnel at an operational level and emphasise the value of input from geographically dispersed personnel and experts, recognising the importance of a flexible, robust, and dynamic emergency response system. Additionally, the authors highlight the need for all stakeholders to utilise the same system for training and conducting exercises, mirroring the conditions of a real crisis (Turoff, 2006). Two hours into the exercise, ICs were asked if they now had a common situational understanding. Their answers show that that was not the case:

"Now we're operating with three maps. The police have their own, the fire department has theirs, and we have ours. It becomes challenging when we try to coordinate the response to injured individuals in the field. I have full control over my personnel, knowing where they are. But then the fire department

has its maps focused on fire incidents, which don't show the location of their personnel" (IC Red Cross).

This understanding was supported by the IC from the police and the IC from The Norwegian Civil Defence:

"We currently have two parallel incidents: injured individuals and the fires. We lack a common map with visual aids that everyone can see to achieve a shared situational understanding" (IC Police).

"We have an issue where the ICs are not staying at the ICCP but instead must leave the site to coordinate their operations. We generally understand the situation's objective, but the details make it feel chaotic" (IC The Norwegian Civil Defence).

The fire and rescue services IC understood the situation differently and argued: *"We have a good situational understanding now, but we're struggling to receive updates from the sector leaders who are extinguishing the fires"*. Summoning up, this strengthens our understanding of map-based tools in use functioning suboptimal as boundary objects (Figure 4, 3a), and lack of interoperability the main course of it not supporting the collaboration in reaching a Shared Representation TZ (Figure 3, 4)

4.2.4. Live video as a successful Boundary Object. The ICF Command Vehicle provided the possibility of a live video feed through a camera placed on the trunk lid (Figure 4). This also served as a boundary object (Figure 3, 3a), and the ICs on the scene used a paper map of the area where they drew lines and wrote relevant information with a marker. This was then live-streamed so that actors from the other levels that were not in proximity of the fire could follow the development of the joint effort. A virtual workspace was initiated by using Microsoft Teams, enabling cross-level cooperation, discussion, and information sharing. Via the Command Vehicle, live video streams from UAVs operated by Fire and Rescue and the Red Cross were shown on a monitor. This complemented the projection of the map and contributed to the shared representation. We argue that when ICs collaborated across levels through the Command Vehicle as the primary boundary object, they transitioned to a Shared Representation TZ (Figure 3, 4) where participants could contribute more jointly to reach common goals (Gorman, 2002). The live feed from the UAVs offered a rich modality that enabled a mutual understanding of the situation (Table 1). By this, the live-stream enabled both vertical and horizontal information sharing and was the most successful COP that we observed during the whole exercise.

Figure 4. Fire Command Vehicle. Photo: Kristine Steen-Tveit

4.2.5. Learning and adopting. Digital map-based tools were problematised in evaluation post-exercise, especially the lack of interoperability and mismatch between geo-location of maps used by fire and rescue and maps available for more extensive collaboration. Representatives from the Red Cross argued that the main problem was that the ICF had no idea where the people out in the terrain were and that this was a big problem. The ICF argued that he needed control over sectors and the actual fire front and that it was of lesser interest to him where the people were. Keeping track of people in the terrain was the sector leaders' responsibility. Information trading during the evaluation was coloured by a discourse on how the common map should be, and we argue that the information trading occurred in a Subversive TZ and that the exercise contributed to new knowledge of the lack of interoperability of the different maps in use emerging (Figure 3, 5). This could potentially lead to a change in IS in use, such as SOPs or other tools for collaboration, in line with organisational learning and double- or triple-loop learning.

5. Discussion and Conclusion

We concur with Boersma and Wolbers who suggest that a TZs in EM is a space where various actors "trade" their ideas about the relevance of available crisis information, and argue that a TZ in EM follows, or at least should follow, a Habermasian, consensus-seeking path rather than a discursive path (Foucault & Nazzaro, 1972; Habermas, 1976), where eventually the key goal of information trading of all actors collaborating in handling crisis is common situational awareness (Endsley, 1988, 2017, 2020). Following this understanding information trading in the Shared

Representation TZ should be a goal, but from our preliminary observations this is rarely a steady state. Information trading and communication is complex. The lifecycle-perspective presented by Collins et al is challenged by the dynamic features of information trading that we observed. When analysing information trading, we should bare this in mind. As an example, information Trading in the response phase can happen in all the presented TZs (Figure 4). We understand Boundary objects in an EM setting as closely connected to both a COP and TSA devices, where they enable both verbal and non-verbal communication in either shared displays or shared environments. Likewise Interactional expertise is closely connected to TSA Mechanisms and shared mental models (Endsley & Jones, 2001).

We see that the use of our novel framework offers a good approach when analyzing past events, demanding collaboration and information trading and sharing in EM, and we see that it can also be beneficial when doing risk assessments and planning for future incidents. We acknowledge that the empirical foundation of this article is not sufficient to argue that the framework will have significant implications for either the practice field or academia, and do not claim this. But from an academic perspective a framework like this can enable dialogue when addressing potential barriers to TSA. In this paper we introduce the existing understanding of Information TZs from an extensive literature review. We argue that the framework first presented by Collins et al. has a relevance when analyzing the use of IS in EM. We present and adapt an extended framework derived from a workshop with participants from both the practice field and academia, and we demonstrate how it can be used by analyzing a full-scale exercise. We argue that the new framework fills an identified gap and has greater explanatory power and the potential to better describe TZs in EM more in detail than previous frameworks by illuminating multiple aspects and characteristics of the information trading and negotiating process. It also adds to the understanding of the relation between COP and TZs. Our research is motivated by an understanding of crisis as contingency, where information trading and negotiating is an ongoing and dynamic process. A framework like we have presented can be valuable when addressing the dynamic characteristics of collaborative efforts in EM and crisis scenarios.

Further research will seek to both validate the appropriateness of our novel TZ framework and validate the relevance of the framework for the practice field. Motivation is understood as being a perquisite for engaging in in information trading, but more research is needed to clarify the connections between intrinsic and extrinsic motivation and TZs.

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