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The impact of interorganizational collaboration on the viability of disaster response operations: The Gjerdrum landslide in Norway

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ABSTRACT

This study investigates the interorganizational collaboration among agencies that responded to a landslide in Gjerdrum, Norway in 2020. It focuses on the crucial role of communication, coordination, cooperation, and knowledge sharing within organizations, and it examines tensions between centralization and decentralization, professional and administrative leadership, planning and improvisation, and external and internal information sharing. To explore this collaboration, we conducted nine interviews and employed the viable system model (VSM) as a conceptual and methodological framework. Through a systemic diagnosis of the search and rescue (SAR) crisis response system's viability and by applying the VSM, the structural, communicational, and functional pathologies in interorganizational collaboration were identified. Thus, this diagnostic approach allowed us to determine the pathological features that challenged the SAR system's effectiveness and viability, including imbalances, inefficiencies in maintaining internal and external interactions, communication breakdowns, and inefficient resource allocation. These insights clarify the structural challenges within the SAR system and underscore the significance of optimizing interconnections, establishing efficient decision-making processes, and improving communication flows to enhance the overall effectiveness of the SAR system.

1. Introduction

"Countries and communities need to develop adaptation solutions and implement action to respond to the impacts of climate change that are already happening, as well as prepare for future impacts" (United Nations Climate Change Secretariat, (UNFCCC, 2021). This organization addresses climate change adaptation, emphasizing that events caused by natural hazards, often informed by climate change, are not isolated incidents. They result from intricate interactions between social and environmental factors (Boin et al., 2020a; Mercer, 2010). To address this multifaceted issue, the research community has formulated practical concepts, principles, and methods to enhance societal resilience and adaptive capacity to events caused by natural hazards. For example, Adger (2010) emphasized the importance of social capital and collective action in building resilience and adapting to climate change, and Barnes et al. (2020) highlighted the duality of social-ecological network structures in terms of their ability to enable learning and internalization of the lessons learned as well as enhance and discourage the adaption process. Collaboration across multiple geographic and organizational boundaries is another key area of enhancing adaptive capacity, enabling better handling of crises arising from natural environmental forces (Therrien et al., 2015).

The postcrisis analyses of several disasters, such as Hurricane Katrina (Kroll & Moynihan, 2021), the California wildfires (Wong-Parodi, 2020), and the 2021 flood in Germany (Netzel et al., 2021), indicated that more structured interorganizational collaboration would have reduced the destructive effects of these events. Given the dynamic nature of events caused by natural hazards, emergency organizations often need to adjust beyond their usual structures to effectively respond to these complex situations, addressing new challenges and tasks (Andreassen & Borch, 2020). Responding to such events requires collaboration between organizations because a single organization may not respond independently due to rapid changes in the environment, a lack of experience, the scope of the task, and insufficient resources (Boin

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& Rhinard, 2023; Rivera & Kapucu, 2015). Interorganizational collaboration can be ensured by each organization systematically sharing their goals and the information they have (Therrien et al., 2015). Moreover, several organizations may be involved in collaborative emergency responses, including police departments, paramedic services, and rescue agencies. Indeed, depending on the scale of the emergency, local authorities, government departments, military forces, and the various businesses of multiple nations may also be involved (Scholtens et al., 2014). Therefore, enhancing resilience in response to these events necessitates an integrated approach to hazard mitigation and resilience planning, including collaboration among interdependent organizations. The lack of integrated decision-making and interorganizational cooperation can significantly reduce the effectiveness of efforts to bolster disaster resilience (Godschalk, 2003).

However, existing research on collaboration in disaster resilience predominantly relies on single-level analyses rather than focusing on the interorganizational interactions between the tactical, operational, and strategic levels within disaster response systems. This inadequacy motivates the current study. Accordingly, we analyze the interorganizational relationships that were observed in the response to the landslide in the small town of Ask in the Gjerdrum municipality in Norway. Due to its coastline and wide mountain ranges, Norway is highly vulnerable to changing weather conditions. The report titled *Climate in Norway 2100* (NCCS, 2017) indicates that gradually increasing temperatures, increased precipitation and extreme rainfall, and increased floods in the future may cause more quick clay slides in certain areas in Norway. Furthermore, some flood and landslide events have been studied to improve risk and crisis management related to natural hazards (Devoli et al., 2018; Kalsnes et al., 2017; Steen & Ferreira, 2020).

This study analyzes interorganizational collaboration in crisis management in Gjerdrum, Norway, using resilience crisis management literature as the basis. We conducted document analysis and interviews with key actors involved in the response to the landslide in Gjerdrum, and we reviewed public documents and media reports, including evaluation reports, instructions, and news articles, to ascertain the background information necessary for analyzing the ways in which different government organizations handled the crisis management tasks for which they were responsible when responding to Gjerdrum's quick clay landslide. We examined the Gjerdrum crisis response network within the context of the National Response Framework using the viable system model (VSM) (Beer, 1984). Herein, "viability" is defined as the crisis response system's ability to survive over time, which necessitates continuous change and adaptation. As an operations research technique (Preece et al., 2013), the VSM provides a holistic framework for understanding how different parts of an organization work together to achieve its overarching goals (Espejo, 2021). This holistic understanding can be utilized both as a design tool and for diagnostic purposes. In this paper, our focus is on the latter as we identify three types of diagnostic issues that could impact the overall performance and effectiveness of crisis response systems: financial, structural, and communication-related. Employing an interpretive approach (Thanh & Thanh, 2015), we also provide insights into the experiences, perceptions, and decision-making processes of individuals involved in the Gjerdrum crisis response operation and the ways in which they took action based on their understanding. These insights facilitated the identification of functionalities and dysfunctionalities in the crisis response network were identified, from which recommendations that can improve the effectiveness and viability of this network are provided. These recommendations offer valuable insights that policymakers and practitioners can use to improve interorganizational collaboration and decision-making processes in disaster response systems, ultimately leading to more effective and resilient crisis management.

Our contribution to the existing literature is threefold. Firstly, we apply a structured framework to enhance the analysis and understanding of the interconnected features of a crisis response operation. It provides valuable insights in terms of decision-making and improving the effectiveness of emergency response efforts, particularly in the context of climate change. Secondly, using a case study approach, we demonstrate how the application of a systemic approach such as the VSM enhances researchers' ability to identify and address challenges within operational contexts as it offers a deeper understanding of the complexities involved. Thirdly, by exploring the interorganizational collaboration, this research contributes to the study of crisis management operations by using systemic tools based on empirical evidence, and it highlights the VSM framework's diagnostic ability to uncover and address challenges within interorganizational dynamics.

2. The theoretical and contextual background

2.1. Collaborative dynamics in crisis management

In a crisis management domain, 'crisis' is a complex and multifaceted term, often characterized in literature as either a disruptive event or process with potentially destructive outcomes (Wang et al., 2016; Williams et al., 2017), emerging under conditions of high uncertainty and time pressure (Boin et al., 2020c). As a result, the conceptualization of crisis management varies widely. At the heart of this discourse lies the debate between Perrow (1984), who argues for the inevitability of accidents in high-risk systems, and Weick (1988), who focuses on prevention and preparation. This manuscript aligns with Weick's perspective, particularly emphasizing the role of interorganizational collaboration in mitigating crisis impacts. Effective crisis management, demonstrated through the coordination of stakeholders and resources in ambiguous environments (Sommer et al., 2018), is essential for realigning disrupted systems. This approach is crucial in managing both event-based and process-based crises, where anticipation and early response are key (Karam, 2018).

The nature of crises often necessitates deviation from traditional organizational structures, highlighting the crucial role of interorganizational collaboration (Ansell & Boin, 2017; Boin et al., 2020b). Collaboration, in this context, is an interactive problem-solving method involving autonomous organizations (Huntsman et al., 2021). Its significance is evident in the responses to events like Hurricane Katrina and the World Trade Centre attacks (Butts et al., 2012; Comfort & Kapucu, 2006). The planning and execution of collaboration in crisis management are complex, entailing communication, coordination, consultation, conflict resolution, consensus building, and cooperation (Comfort, 2014; Margerum, 2011). These processes are essential for successful interorganizational cooperation, often challenged by the rapidly evolving environment, task complexity, limited resources, and lack of prior experience (Christensen & Lægreid, 2008; Kapucu & Garayev, 2011).

Additionally, the complexities of collaboration in crisis management are highlighted by the differing goals, communication styles, and cultures of organizations involved in managing such crises. The theory advocates for strategies that effectively address immediate situations while also considering systemic integrity and resilience. Examples from scenarios like the responses to Hurricane Katrina and the World Trade Center attacks illustrate the practical applications of this theoretical approach. Ultimately, integrated crisis management theories (Bundy et al., 2017), promotes a harmonized approach in crisis management – one that adeptly addresses immediate challenges while ensuring the systemic robustness against future crises. Coordination in this regard becomes a critical function, balancing designed and emergent strategies to adapt to volatile situations (Comfort, 2014; Olsen et al., 2023; Sydnes et al., 2021). Meanwhile, communication, integral to effective collaboration, often faces challenges such as differences in terminology, information overload, and legal constraints on information sharing (Allen et al., 2013; Wolbers et al., 2018). Thus, establishing trust through preexisting networks and competencies becomes vital in navigating the complexities of interorganizational communication during crises (Manoj & Baker, 2007; Meyerson et al., 1996).

Aligned with these insights, the theory of collaborative dynamics in crisis management underscores the interplay between local adaptiveness and global maladaptiveness. This concept, elucidated by Woods and Branlat (2011), indicates that adaptive performance, while locally beneficial, can introduce systemic vulnerabilities. Adaptive performance, here, is viewed not just as a local, immediate response to crises, but also through the lens of its impact on the overall system's resilience and vulnerability. The interplay of adaptation at various levels introduces a paradox: actions that are beneficial in a localized context may inadvertently lead to brittleness or vulnerabilities at a broader, systemic level. This dynamic underscores the complexity of interactions across various levels of crisis management systems. In this concern, Eide et al. (2012) highlight three key challenges that are indispensable for proficient crisis management: (1) robust communication within and among agencies, crucial for coordinated and informed decision making; (2) situation awareness for strategic agility; and (3) cross-organizational synergy. Localized adaptive strategies, though effective in immediate contexts, can contribute to broader systemic challenges. The differing goals, communication styles, and organizational cultures of various stakeholders in crisis management often lead to complex dynamics (Bergström et al., 2016). In such environments, there is a need for immediate and effective localized responses that are also aligned with the overall stability and efficacy of the larger system. This approach advocates for integration in crisis management, recognizing and harmonizing the interdependencies between local actions and global system stability. It emphasizes strategies that efficiently address immediate crises while safeguarding the systemic integrity and resilience against future crises (Olsen et al., 2023).

2.2. The viable system model (VSM)

The VSM, developed by British cybernetician Stafford Beer (1979, 1983, 1984), is a holistic management model based on systems thinking. It consists of five interdependent subsystems that interact to ensure the viability of an organization. When applying the VSM, Fernandes and Tribolet (2019) emphasized the principle of recursion, which involves viewing an organization as a viable system contained within a set of viable systems. This principle is integral to the essentiality of interrelated subsystems that provides necessary and sufficient conditions for any social technical system's viability. An incomplete or ineffective management system can weaken or threaten organizations' viability. Therefore, to ensure cohesion and self-organization, the VSM requires these subsystems to iteratively work together at all levels within a recursive structure that comprises autonomous wholes within autonomous units. Thus, by analyzing the structures, components, and relationships between these subsystems that include key processes, communication, and information flows, the VSM provides a comprehensive overview of an organization's network model (see Fig. 1).

The VSM, as depicted in Fig. 1, identifies three main entities in a self-organizing system: operations, management, and environment, each represented uniquely as a circle, a rectangle, and an ellipse, respectively. These entities are interconnected through five systems, essential for the system's viability and achievement of its objectives. System 1 focusses on the primary activities or tasks required to achieve the system's purpose, such as the search and rescue (SAR) operations conducted by SAR teams. System 2 deals with coordination issues and ensures that different primary activities do not conflict with each other. System 3 controls and manages the operational units, assesses resource allocation, and builds the primary activities into a larger whole by linking subsystems with the system. System 3* audits intra- and extra-environmental behavior by providing information to System 3, to ensure the compliance of the targets specified by system 3 and the rules and regulations promulgated by system 2 (Rezaee et al., 2019). System 4 contributes intelligence by monitoring external factors and anticipating changes that may affect the organization. On the other hand, System 5 plays a crucial role in strategic decision-making and establishing the overall goals and direction of the system. It relies on the insights gathered from System 4 to make well-informed decisions, even in the face of higher levels of risk and uncertainty inherent in sporadic trends (Gallego García et al., 2019). Continuous monitoring and adjustments by Systems 4 and 5 would be crucial due to the unpredictable nature of these trends, ensuring the system's viability and the achievement of its objectives in a dynamic environment.

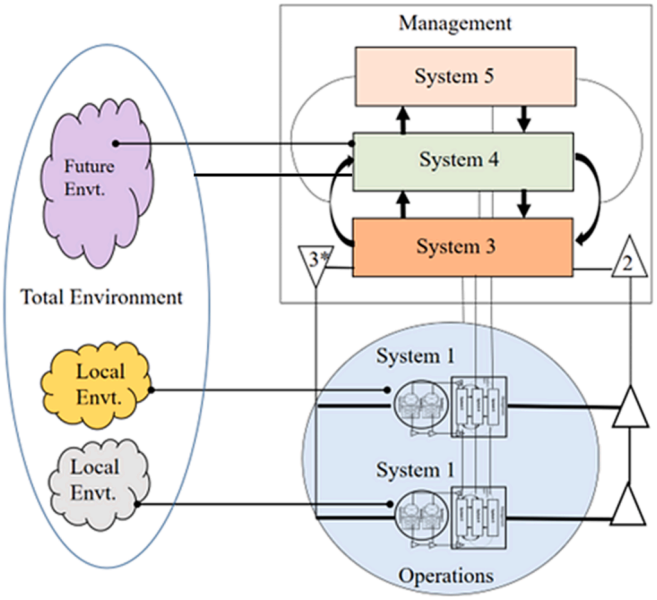

Fig. 1. A Simplified Illustration of Beer's (1985) The Viable System Model (VSM).

Beer (1984) emphasized the importance of the "Law of Cohesiveness" (p. xii) in organizational design and management, which relates to maintaining a balance between central control and local autonomy. If this balance is disturbed, it can create tension and destabilize the system. The VSM features a unique alarm signal called the "algedonic signal". It is designed to trigger rapid responses when required, emphasizing the importance of addressing critical issues promptly. Importantly, this signal can originate from any part of the organization and at any level of recursion, allowing individuals, teams, or departments to raise alarms if they identify concerns with significant implications for the entire system (Beer, 1983; Preece et al., 2015). In Fig. 1, the algedonic channel is represented by a direct link from system 1 to system 5, facilitating effective management of urgent critical situations by conveying important signals.

The VSM has been widely applied as a conceptual tool for organizational analysis and redesign as well as for managing change. Its application has been extended to inform policy development in national systems of innovation (Devine, 2005), disaster response operations (Preece et al., 2013), strategic planning processes (Stephens & Haslett, 2011), multiagency arrangements for combating organized crime (Brocklesby, 2012), and enhancing organizational resilience (Ruiz-Martin et al., 2017). The VSM has also been utilized as a framework to guide organizational adaptive responses (Cardoso Castro, 2019), to monitor viability and sustainability in healthcare organizations (Saviano et al., 2018), to review disaster risk reduction activities (Shaw et al., 2020), and to explore the application of the total defense concept during the COVID-19 pandemic (Pollock & Steen, 2020).

3. Methodology

This study examines the interorganizational collaboration within the Norwegian SAR Service to determine its viability. To address the conceptual nature of viability, we employed sensitizing concepts that

provided a general framework for approaching empirical instances and generating evidence of selected aspects (Faulkner, 2009). Furthermore, we adopted an explanation-based approach with implicit counterfactual reasoning (Stern, 1997). We also employed a qualitative research design that triangulated document analysis and semi-structured interviews in three stages to answer our research question (see Fig. 2).

In the first stage of the research, the focus was on the theoretical aspects of the Viable System Model (VSM), establishing the groundwork for the exploration into the Norwegian Search and Rescue (SAR) system's handling of the Gjerdrum landslide. This initial phase played a crucial role in determining the study's scope and identifying essential documents and stakeholders for the second stage. The VSM framework was then applied to examine the collaboration between different SAR service actors in the case study. The complexities of this collaboration are further explained in the subsequent sections of the study. The final stage involved a detailed analysis of the collected data, which was derived from both report reviews and interviews. What follows is a brief overview of our case study, detailing the data collection process, and explaining how we employed the VSM to analyze our findings.

3.1. Case study

3.1.1. The Norwegian SAR system

The Norwegian Search and Rescue (SAR) system, established by Norwegian authorities, is responsible for the management and execution of SAR operations across different environments such as land, sea, and air. While the SAR system itself does not possess its own field resources, it collaborates with various entities for contributions. These include the national police force, municipal fire departments, ambulance services operated by regional public health enterprises, and a combination of other public and private organizations, including volunteer-based entities (Rimstad et al., 2014). The police play a pivotal role in overseeing rescue activities within their respective geographical areas, with their operation centers, incident commander's command post (IL-KO). Fig. 3 provides an illustration of a segment of the Norwegian SAR system that aligns with the scope of the study.

In 2012, the Norwegian Stoltenberg government introduced collaboration as a fourth national emergency preparedness principle alongside responsibility, equality, and proximity. This addition emphasizes the importance of interorganizational collaboration in response to terror attacks, and other major incidents. The principle of collaboration promotes resilience in complex situations and recognizes the need for different organizations to effectively work together to address emergency situations and improve overall preparedness.

3.1.2. The Gjerdrum landslide

The 2020 Gjerdrum landslide occurred in Norway in Ask village, which is Gjerdrum's administrative center. This quick clay landslide spanned an area of 300 x 700 m, and the resulting debris flow affected an additional 9 ha. Although some individuals were rescued and others evacuated themselves, 10 people lost their lives, and several buildings were destroyed, resulting in an estimated cost of over 100 million US dollar (Nikel, 2021). The Joint Rescue Coordination Centre report (JRCC, 2021) stated that during the early phase of the Gjerdrum landslide, the primary challenge was understanding its extent and requesting appropriate resources. Emergency situations are often characterized by uncertainty and limited information, and incidents that occur during the night or under adverse weather conditions, such as the Gjerdrum landslide which happened at night during the Christmas period, exacerbate the ability to gain relevant information. The landslide required an intensive SAR operation due to the significant number of people that needed immediate attention, and the subsequent breakdowns in infrastructure, such as the water supply, sewage, roads, and electricity, in the area added to the complexity of the operation (JRCC, 2021). The main actions taken by various organizations during the crisis response phase are depicted in Table 1. In this crisis, the Eastern Police District acted as the local rescue center and led the rescue operation.

During the Gjerdrum landslide crisis, the situation evolved over several weeks. As the crisis reached a critical point on 5 January, the focus of the operation changed significantly. After continuous evaluation and consultations with health authorities, the police department involved in the search and rescue (SAR) operation concluded that the chances of finding survivors were no longer viable. As a result, they made the difficult decision to suspend search efforts. At this stage, seven individuals had been found deceased, with three still missing. This led to the formal transition to the 'Search for Presumed Deceased (SEAO), a decision that was not taken lightly but reflected the harsh reality of the situation. As detailed by JRCC (2021, p. 57), this shift marked a substantial change in the nature of the response, involving new risk assessments and resources. The decision, announced in a press conference led by the police chief, signified the community's grappling with the aftermath of the disaster. At the time of the transition to SEAO, the Local Rescue Service (LRS) had a clear overview of the extent of the clay landslide: 27 housing units were initially affected by the landslide and, in the following hours and days, several more collapsed. In total, 1,620 people were registered as evacuated, highlighting the extensive impact of this catastrophic event (JRCC, 2021, p. 57). The search continued, and on 9 February two more deceased individuals were found. The last missing person was tragically discovered on 22 March (Hagfors & Alsaker-Nøstdahl, 2021). Following the recovery phase, efforts have been shifted towards investigating the cause of the landslide and securing the area to prevent further incidents.

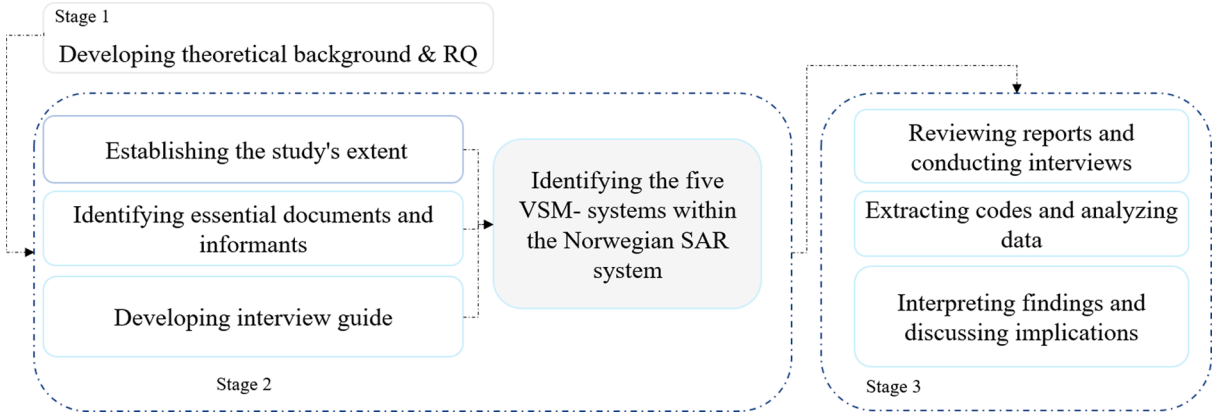

Fig. 2. The Methodological Design.

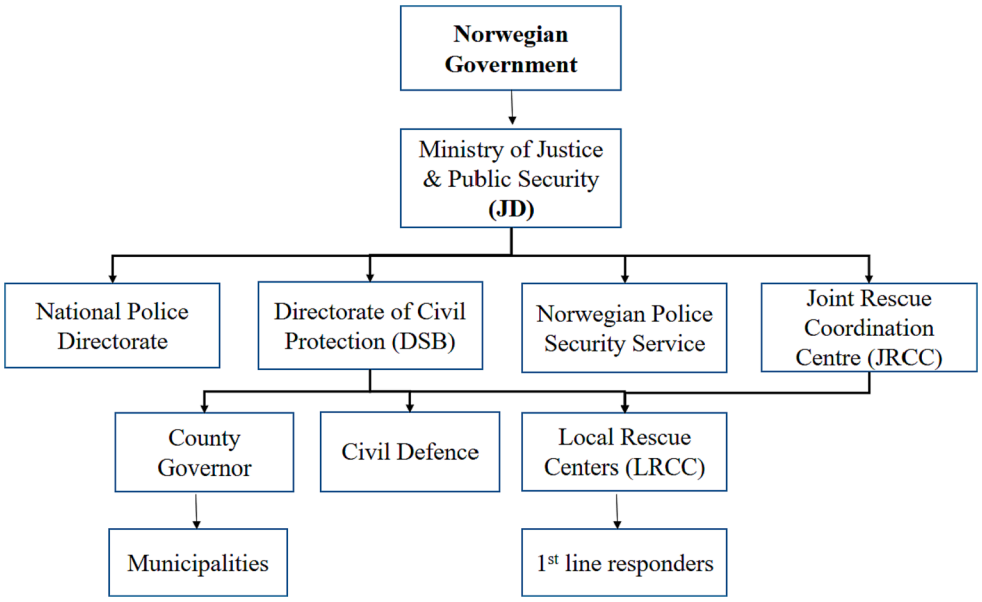

Fig. 3. A Portion of the Norwegian SAR System.

3.2. The data collection process

To understand the dynamics of the Gjerdrum landslide crisis management, our goal was to interview officials from the Gjerdrum municipality, and the police department involved in the crisis response. This effort coincided with legal charges initiated by the police against the municipality for alleged failures in emergency protocols and erosion control in 'Tistilbekken' following the 2020 landslide (Bortelid Mæland, 2022). Despite these charges being dismissed in November 2022 (Sundby, nov. 2022), legal sensitivities led to several officials declining to participate in interviews. Nonetheless, we successfully conducted two interviews with the municipality and three with the police department. To supplement these interviews, we also analyzed media reports and official documents for additional insights.

The Semi-Structured interviews

We conducted nine semi-structured interviews using digital platforms. They were conducted from September 2021—February 2022, with an average duration of 60 min each. purposive sampling as per Campbell et al. (2020), we selected respondents with significant expertise and direct involvement in the SAR operations or strategic support during the Gjerdrum crisis response. This selection process was critical for acquiring a diverse and comprehensive understanding of the operational context. Our respondents represented key actors in joint crisis management, including the affected municipality, police, county governor, and a representative from the Norwegian Directorate for Civil Protection (DSB). This diversity enabled us to gather extensive information about the case at hand, enhancing the applicability and relevance of our findings to other scenarios where rescue services, municipalities, and county governors collaborate in crisis response. The participants, anonymized and referred to in subsequent discussions (see Table 2), provided informed consent. The consent form detailed the study's objectives, methodology, potential risks, and outcomes, emphasizing the voluntary nature of their participation and their right to withdraw at any time. The choice of semi-structured interviews was deliberate, aiming for in-depth discussions and a richer understanding of each interviewee's experiences and perspectives.

All the interviews were recorded and transcribed. The transcriptions were then shared with the coauthors for the purpose of data analysis. To increase the reflection among the informants, they received an information sheet that detailed the purpose of the study and the interview questions in advance. To improve the study's reliability, further verify the empirical findings, and review the information, we returned the transcripts to our participants and asked them to provide feedback on their transcripts in a one-week window (as we planned).

Document analysis

This study extensively analyzed two key investigation reports, which together comprised 188 pages. The first report (Grahl-Jacobsen et al., 2021), spanning 84 pages and produced in 2021 by Rogaland Fire and Rescue IKS, was commissioned by Øvre Romerike Fire and Rescue (ØRB) to evaluate their crisis management strategies during the landslide in Gjerdrum. This evaluation primarily focused on documenting operational experiences and assessing the achievement of objectives in line with the organization's focus areas. Data was collected from primary and secondary sources, including interviews, After Action Reviews (AAR), and surveys for firsthand operational insights, alongside documentation from the Crisis Management Information System (CIM) for structured incident records.

The second report, comprising 104 pages, was developed by The Joint Rescue Coordination Centres (JRCC, 2021) and presented to the Ministry of Justice and Emergency Preparedness in June 2021. It scrutinized the rescue operation and crisis management during the landslide. This collaborative evaluation involved the Central Rescue Service, the Directorate for Community Safety and Emergency Preparedness, and the Norwegian Police Academy. It featured detailed analyses of the incident, focusing on the emergency response and the inter-agency collaboration. The report included interviews with over 100 individuals involved in the incident management. Interviewee selection was influenced by recommendations from various actors and the evaluation group's knowledge of the event's participants (JRCC, 2021, p. 21). This methodology ensured a thorough examination of the emergency response and the interplay between different national safety and emergency organizations.

Together, these reports provided a comprehensive perspective on the challenges and intricacies encountered in these significant emergency response operations.

3.3. The data analysis

We applied thematic analysis (TA) (Clarke & Braun, 2017) to determine patterns or themes within the dataset. TA generally involves a systematic process of organizing and interpreting qualitative data through several steps. We first familiarized ourselves with the data by

Table 1
The Gjerdrum Landslide Emergency Response Operation Timeline 30.12.2020 – 01.01.2021.

Wednesday, 30.12.2020
03:56: Power outage, landslide occurs.
03:59: Emergency services receive the first message.
04:05: The fire brigade teams assigned tasks; JRCC in Sola was alerted.
04:07: The Rygge helicopter crew and Oslo alerted; distress calls were received.
04:15: The Gjerdrum municipality (mayor) initiates the response to the crisis.
04:21: First responders (ambulance) arrive on site.
04:28: The temporary incident command centre is established.
05:09: First police helicopter arrives in the area of the landslide.
05:20: The Rygge rescue helicopter begins search.
05:24: Report of about 50 exposed houses.
06:20: Evacuation buses arrive; 15 people are taken to the Olavsgaard hotel.
06:36: The first patient reaches Oslo University Hospital.
07:14: Media monitoring started.
07:18: First drone for landslide mapping deployed.
07:45: SAR Queen resumes aerial coverage.
07:46: Evacuation of houses on the edge of the landslide.
08:09: The gathering point moved to Gjerdrum Youth School.
08:17: Rygge helicopter at IL-KO for unified search and command.
13:30: Complete evacuation of residents in landslide-edge houses.
15:24: The operations centre reports 22 individuals still not located.
15:30: New landslide; several houses collapse.
15:56: Updated count of missing individuals: 18 individuals still not located.
20:00: Police end the search in the red zone; Drone and helicopter search continues.
Thursday, 31.12.2020
00:25: Fire brigades set up weather monitoring posts.
15:23: Possible new landslide at Kokstad farm; geotechnicians assess.
15:30: Sea King starts the evacuation route; personnel evacuation begins.
15:33: Sea King prepares; cracks are observed north.
15:45: Operation of the Sea King evacuation route.
16:00: The drone inspects the Kokstad Farm; evacuation confirmed.
22:53: The emergency order and response plan for Jan. 1–3 is initiated.
Continuous: Search operations are ongoing.
Friday, 01.01.2020
05:04: Excavation starts from Brådalsvegen towards houses.
07:53: Military builds a bridge to high-risk area.
09:05: Request for 2 fire team units for road construction.
11:15: Road construction to buildings begins; tactical plan set.
13:40: The Fire Department requests Trondheim assistance.
14:30: USAR Trondheim requested, departs around 15:00.
14:36: First casualty discovered at IL-KO.
15:33: Area cleared; search dog deployed.
16:22: Continuous SAR operations with drones and helicopters. A crew of Swedish urban search and rescue (USAR) experts assists with the operation.
22:28: The USAR team from Trondheim departs for Gjerdrum.
Continuous: Search operations are ongoing.

carefully reviewing the dataset after the transcription of the interviews, which helped us develop a general sense of the contextual issues associated with the Gjerdrum crisis management operation and identify the initial ideas and potential themes. After this, we generated initial codes using NVivo 14 to highlight relevant words, phrases, or sections of the text in accordance with the research question. The coding process was guided by the conceptual framework of the study (Section 2). We identified a total of 42 codes, thus capturing the meaning of the data, and determined the broader patterns of meaning, leading to the identification of 16 first-order themes, including collaboration, coordination structure, and communication (see Fig. 4).

After reviewing and analyzing the identified themes, we refined and aggregated them into a final set comprising five themes: challenges, communication, collaboration, communication, and functional and structural. The identified themes were then used to address interorganizational collaboration among the actors involved in the Gjerdrum crisis response operation, with the VSM being applied to examine the operational and tactical levels of the SAR service system. This involved identifying the system in focus, modeling its structural activities to understand the complexity, and examining its functional, structural, and

Table 2
Interviewees, their roles, responsibilities, and associated organizations in the context of Gjerdrum crisis management.

No.	Role in Crisis Management	Responsibilities	Organization
P1	Operational Leader	Manage the crisis in Gjerdrum; oversee response efforts; coordinate teams and agencies; make critical decisions; manage resources.	Police Department
P2	Police Liaison and Contact Officer	Engaged in operational and preventive work in the police, the interviewee served as the permanent police contact for Nannestad and Gjerdrum municipalities and had a role as a liaison during the landslide crisis. As a liaison, focused on preventive efforts and actively maintained dialogue with municipal leadership, community organizations, and businesses, contributing to the overall crisis management and response strategy.	Police Department
P3	Incident Commander in East Police District	Appointed as a liaison during the Gjerdrum landslide crisis. Involved in coordinating tasks outside the landslide area, such as retrieval of belongings and animals, and played a pivotal role in establishing operational strategies to manage practical aspects of the crisis response.	Police Department
M1	Emergency Preparedness Coordinator	Oversee emergency preparedness and response; managing multiple roles including data protection advisor, information officer, and political secretary; part of the crisis management team during emergencies, collaborating with key roles like mayor, deputy mayor, and chief medical officer in crisis leadership.	Municipal Administration
M2	Chief of Technical Services	Responsible for all municipal buildings, operations, and projects; in charge of municipal roads and relations with Viken region; oversees water and sewage systems, parks, swimming areas, and recreational zones; maintains municipal properties.	Municipal Technical Services
D1	Fire and Rescue Services Expert	Over 21 years in fire and rescue; various roles including acting fire chief; deputy head of emergency services in Upper Romerike; currently focuses on	Directorate for Civil Protection and Emergency Planning (DSB)

(*continued on next page*)

Table 2 (*continued*)

No.	Role in Crisis Management	Responsibilities	Organization
		emergency communication network support for defense, civil defense, and fire services in DSB.	
D2	Specialist Director at DSB	Specializing in the total defense program and addressing hybrid threats, including disinformation, contributed to the crisis management efforts, particularly in aspects related to information security and strategic communication.	Directorate for Civil Protection and Emergency Planning (DSB)
C1	County Governor's Office Staff Member	Initially supported the on-duty staff from home; became the liaison to Gjerdrum, acting as a link between the County Governor's office and Gjerdrum's crisis management; gathered and relayed information.	County Governor's Office
C2	Representative of the County Governor in Police Rescue Management	Represented the County Governor in police's rescue management during the Gjerdrum crisis; involved in overseeing municipal emergency preparedness and response; managed coordination between different emergency services.	County Governor's Office

communication-related issues.

4. Findings

4.1. The SAR system through the lens of the VSM

The Gjerdrum crisis demonstrated the effectiveness of the Norwegian Search and Rescue (SAR) system's crisis management capabilities. This intricate network, composed of various collaborative parts, operated efficiently during the landslide crisis. In the impacted municipality, home to 7,000 people, the crisis was substantial, necessitating the evacuation of over 20 percent of the population. The mayor of the municipality characterized the situation as both vast in scale and extremely serious, highlighting the gravity of the events at that time (Husøy, 2020). Fig. 5 and Table 3 demonstrates the application of the VSM's five systems in analyzing the management of the SAR operations during crises and tasks.

The tasks of crisis response participants are detailed in Table 3, while Fig. 5 illustrates the environment as a fundamental component of VSM modeling. The following sections- consolidated paragraph that encompasses the dynamic operational environment of Systems 1-5- explain the main challenges and characteristics of the operational environment, emphasizing its complexity and the necessity for adaptability and strategic decision-making within this context.

System 1

Municipality:

Gjerdrum municipality encountered key challenges, with multi-agency collaboration at the forefront. This coordination required aligning diverse groups, including psychosocial crisis teams and medical personnel, highlighting the complexity of orchestrating a unified response for the EPSs. The municipality's approach had to be adaptable, covering a broad spectrum of requirements ranging from medical care to information dissemination, necessitating a comprehensive service strategy. This strategy had to account for both physical and psychological aspects, further complicating operational tasks. Additionally, managing resource allocation and information flow was crucial. The municipality's prompt resource mobilization following the alert, particularly during a holiday period, emphasized the logistical hurdles. The involvement of law enforcement in evacuee registration and the imperative for effective communication and logistical planning in regular meetings with stakeholders underscored the complex nature of information management in a constantly evolving crisis environment. These factors collectively illustrate the municipality's role in a demanding and dynamic operational context.

Fire brigades:

In the context of the Gjerdrum landslide disaster, the fire brigades faced a series of complex operational challenges. A primary concern was the thorough conduction of job safety analyses, crucial given the intricate nature of their tasks. This included rescuing trapped individuals, where they had to assess structural stability, identify potential hazards such as gas leaks, and manage the physical strain on responders. Additionally, effective collaboration with numerous domestic and international actors was a formidable challenge. Coordinating resources and

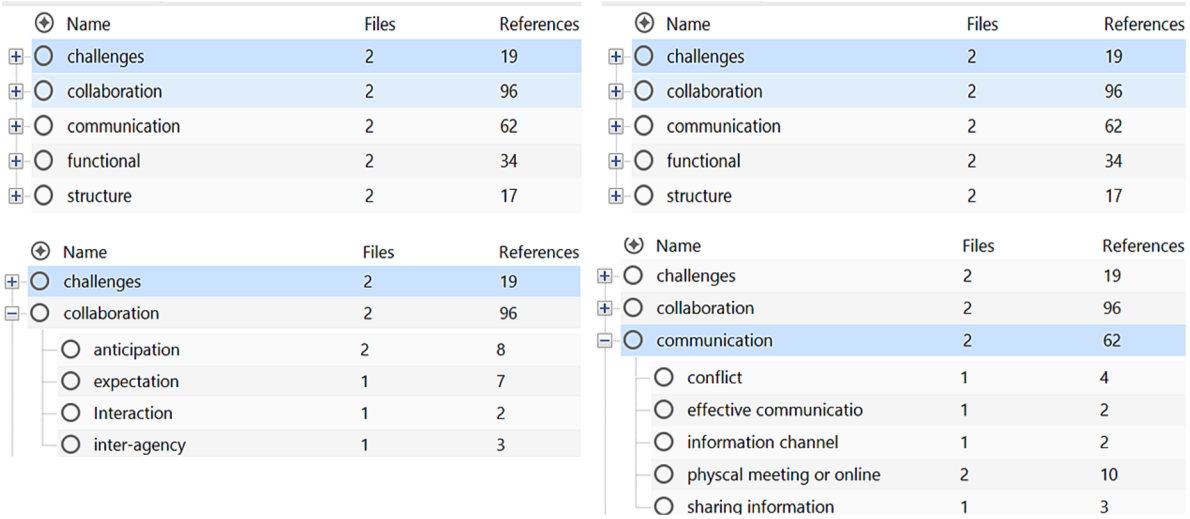

Fig. 4. The Codes and Themes Identified.

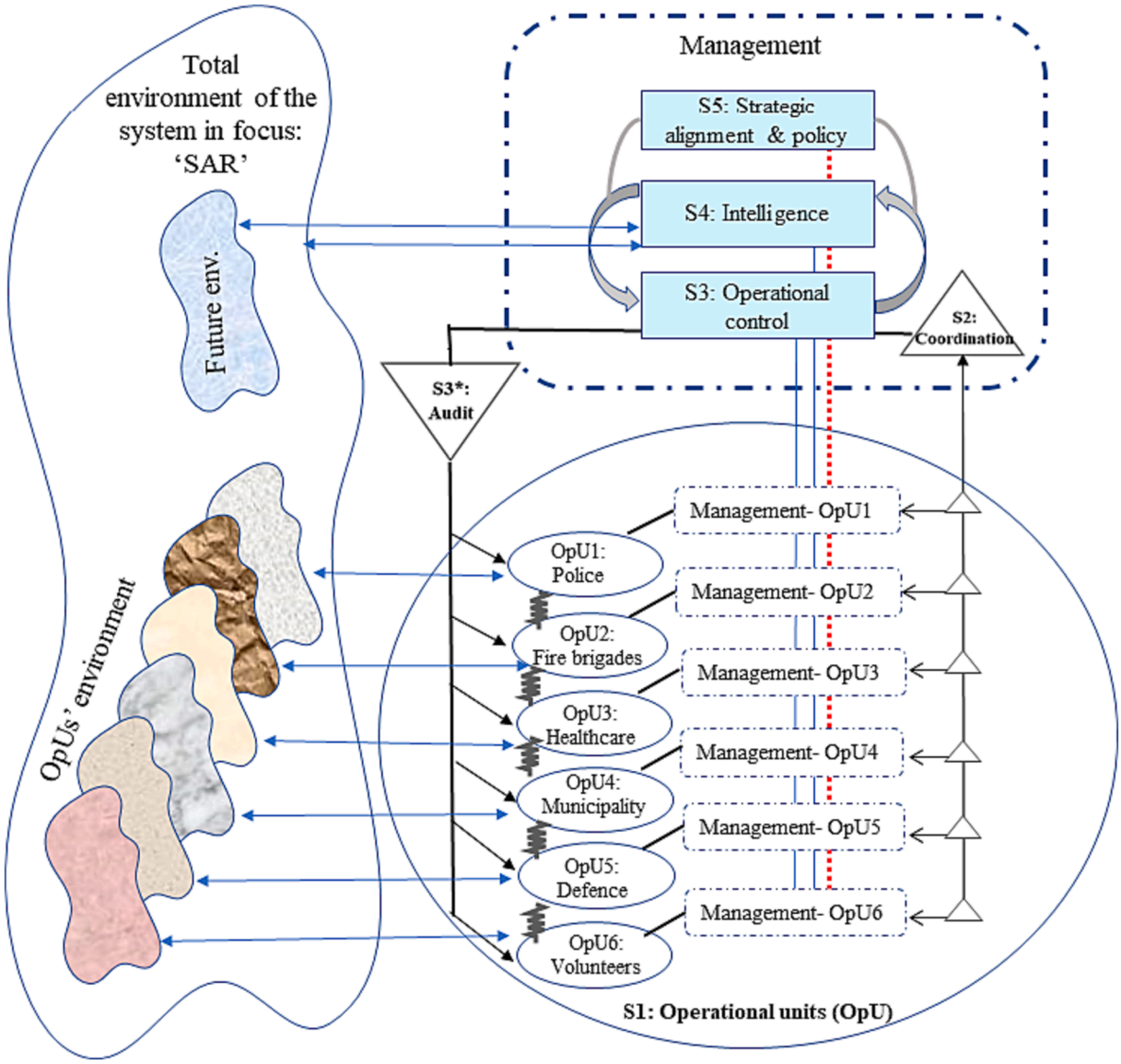

Fig. 5. A Simplified Illustration of VSM components for analyzing the Norwegian SAR system in the Gjerdrum Landslide crisis, with algedonic channel (S1 to S5) indicated by dashed red line. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

aligning priorities among teams from Canada, the USA, Sweden, and other agencies required robust communication and consensus-building efforts. Furthermore, the brigade had to devise and implement or the so-called 'quasi-solutions' (Andersen, 2021, April 14) — improvised methods to address unexpected challenges that arose in the rapidly changing landscape of the disaster. Finally, responders grappled with the psychological aspects and emotional strain inherent in such operations. The discovery of personal belongings amidst the wreckage created a deep emotional connection to the mission, highlighting the need for psychological support and recognition of the impact on responders' well-being (ibid).

Health care services:

During the Gjerdrum crisis, healthcare services and emergency responders faced a demanding operational environment. Key challenges included rapid rescue operations, where 15 individuals were extricated from the landslide area, requiring immediate medical care for injuries and hypothermia, the elderly and individuals with developmental disabilities from local care homes (JRCC, 2021, p. 38). Communication issues complicated these efforts, particularly in coordinating air rescue operations and establishing effective triage zones. Managing air traffic added complexity, necessitating coordination among various entities, including air rescue services and airport control towers. Concurrently, the crisis highlighted the need for efficient resource management, as multiple relocations of vulnerable groups were necessary due to operational challenges in temporary care facilities. Infection control, especially in emergency sites and communal areas, was crucial. The situation also underscored the significant emotional and psychological impact on victims and responders, emphasizing the importance of psychological support. This scenario demonstrated the necessity for enhanced training and preparedness in handling complex emergencies, showcasing the intricate interplay of rapid response, effective communication, resource management, public health concerns, and psychological support in crisis management.

Police department:

The operational environment for the police department during the Gjerdrum crisis was characterized by the necessity for detailed coordination and clear definition of roles, especially between the police and local municipalities. This was crucial for the effective establishment and management of EPSs. The complexity of operations was heightened by the need for seamless inter-agency collaboration and the transition of

Table 3
System 1–5: Participants and their assigned tasks.

Systems 1–5 & participants	*Key tasks*
System 1- Municipality (M):- Gjerdrum M. (GM)- Ullensaker M. (UM)- Lillestrøm M. (LM) *EPS: Evacuee Reception Centre	- GM: Providing support for evacuees and relatives - GM: General population care - GM: Crisis management for essential services and infrastructure - UM: managed EPS* Clarion from the start; Gjerdrum M. requests them to continue during New Year's. - LM: took formal charge of EPS Olavsgaard from Dec 30. Olavsgaard served as an evacuation center, Clarion as a center for evacuees and relatives. - Drone search/air coordination
System 1- Police - Oslo Police District - East Police District (LRS East) *IL-KO: incident commander's command post	- LRS: Coordinated and led the rescue operation through the local rescue center: - Rescue and evacuation - Summoning and operation of the rescue management - Establishment and leadership of the IL-KO* - Responsibility for registering involved persons - Contact with and information to next of kin - Identification and handling of the deceased - Notification and arranging the evacuation of people in risk-prone areas - Guard duty and barriers - Search for presumed deceased
System 1- Fire & rescue services (FRS) & Urban Search and Rescue (USAR) teams - Upper Romerike FRS - Lower Romerike FRS - Oslo FRS - East 110 central	- Conducting search and rescue operations to locate and extract individuals trapped or injured in landslides, using specialized tools and coordinating with other agencies. - Collaborating with local authorities to evacuate residents from landslide-affected areas, managing traffic and assisting vulnerable individuals. - Identifying areas at risk of further landslides, establishing safety perimeters and implementing protective measures in collaboration with specialists. - Setting up emergency medical stations for immediate care of landslide victims and coordinating with other medical services for comprehensive support. - Creating a central command system to manage and coordinate emergency response activities, ensuring effective collaboration among various agencies. - Informing the public about landslide risks and preventive measures.
System 1- Health services - Oslo & Akershus University Hospital - Air Ambulance Service Lørenskog & Oslo University Hospital - Municipal health services - Norwegian Centre for Violence and Traumatic Stress & Regional Resource Centre for Violence and Traumatic Stress	Coordinating and lead the health care response: - Assisting rescue and evacuation - Immediate health assistance to evacuate - Transportation to hospitals and treatment of the injured - Representative in the rescue management - Aiding municipalities' health preparedness - Liaison at the IL-KO
System 1- Defence: - Norwegian Joint Headquarters – 333 Squadron Andøya (P3 Orion aircraft) & 337 Squadron Rygge (Bell helicopters) & 330 Squadron - Norwegian Special Operations Forces - The Army engineers	- Air Coordination & Air Support Transport - Map production- Engineering services (bridge laying) - Guard duty and security - Chaplain services - Providing fuel truck for helicopters-

Table 3 (*continued*)

Systems 1–5 & participants	*Key tasks*
- Andøya Space Center - Drone operators	Search dogs (on standby) - Representative in the rescue management team - SAR helicopter from Rygge & Sola- Search with drones (Andøya)- Production of 3D maps (Andøya) - Command and control for drone operations
System 1- The Civil Defence: The Home Guard	- Provided tents, lighting, heating, power, and various equipment at the site of the incident.- Security (at Gjerdrum's cultural house and at EPSs) .- Represented in the Incident Command (IL-KO) , rescue management, and the municipality's crisis management team. -Helping with the water supply and pumping.
System 1- Voluntary organizations: - The Norwegian Church (TNC) - Norwegian People's Aid (NPA) - Red Cross Rescue Corps - Norwegian Rescue Dogs - Norwegian Radio 'Relæ Liga' (NRRL)	- Providing Advisory Support in Rescue Management: Assisting at the EPSs, and keeping the church open for mourners (TNC). - Assisting with the evacuation of residents and offering support in safely relocating residents from the affected areas. - Providing Psychosocial First Aid to Evacuees - Managing the visitor center: Overseeing operations.and services at the center established for visitors and affected individuals. - Providing various transport support. - Maintaining search and rescue dogs on standby: Keeping canine units ready for deployment in search and rescue operations. - Participating as a member in the decision-making and operational planning of the rescue efforts.- Implementing SARTopo Mapping System in IL-KO (NPA) .- Ensuring the registration and tracking of the rescue teams (NRRL)
System 2: - The Norwegian Directorate for Civil Protection and Emergency Planning (DSB)	- Providing support to Civil Defense operations. - Monitoring Emergency Network traffic and ensuring a portable base station is ready in Gjerdrum. - Receiving and relaying status reports between the County Governor of Oslo and Akershus and the Ministry of Justice and Public Security/Crisis Support Unit. - Assisting in the mobilization of the Swedish Urban Search and Rescue (USAR) team. - Coordinating crisis management activities beyond the actual rescue mission. - Organizing a cooperation conference on December 30 for information exchange and to foster a common understanding of the situation.
System 3*: - Norwegian Water Resources and Energy Directorate (NVE) - The Norwegian Communications Authority (NCA) - Norwegian Geotechnical Institute (NGI)	- Assisting in establishing an access road and monitoring landslide development with helicopters and drones for rescue operation safety. - Conducting ground and geotechnical assessments in evacuated areas to identify safe reoccupation zones and advising on essential task execution in these zones. - Participating in community events to

(*continued on next page*)

Table 3 (*continued*)

Systems 1–5 & participants	*Key tasks*
	provide expert information and address concerns and questions from affected residents. - NCA: Monitoring telephony and electronic communication systems.NGI: Providing geoscience assistance and advice on potential landslide development, understood as risk assessment for personnel working in the landslide pit (e.g., evaluating the timing of search operations in the landslide pit, questioning if they could have commenced earlier during the rescue mission) .
System 3: - Norwegian Police Directorate (POD) - Joint Rescue Coordination Centre Southern Norway (JRCC)	POD Conducting landslide cause investigations and compiling reports for legal and future reference, while analyzing situational updates from System 1, the County Governor, and the South-Eastern Norway Regional Health Authority. POD: Taking charge of traffic operations during the crisis, ensuring smooth flow for emergency vehicles and implementing necessary control measures. POD: Supporting the Local Rescue Center East in terms of resource and other needs. JRCC: Coordinating rescue efforts: Held overall responsibility for coordinating the rescue effort and support to the Local Rescue Coordination Centre East, including allocating aerial resources. JRCC: Providing reports and updating information to the Ministry of Health and Care Services.
System 4: - County Governor (CG) - Multiconsult	CG: Serving as liaisons in Gjerdrum, reinforcing crisis staff and coordinating at the regional level. Participating in the LRS rescue management and reporting to DSB on the coordination channel. Multiconsult: Conducting geotechnical, geological, and risk assessments to understand landslide causes, area stability, and future risks and providing critical insights and response recommendations, enacting plans to mitigate future landslide risks, including slope stability analysis and safety strategies.
System 5: The Norwegian Directorate of Health	- Receiving situational reports from the County Governor and the South-Eastern Norway Regional Health Authority. - Providing updates to the Ministry of Health and Care Services.
System 5: Ministry of Justice and Public Security	- Collecting information to provide a basis for the strategic decision-making within the ministry and government.

disaster site control from police to municipal authorities, which required precise guidelines and a clear understanding of each entity's responsibilities. The involvement of Urban Search and Rescue (USAR) teams, composed of members from varied backgrounds, introduced additional complexity (JRCC, 2021, p. 45). Coordinating these diverse teams, each with unique competencies and equipment, demanded extensive synchronization and joint training, particularly for combined air and ground rescue operations. The police's directive role in leading these multi-agency teams to the Incident Command Post (IL-KO) at Nystulia underscored the necessity for a cohesive command structure. This was vital not only for effective operations but also for ensuring order and safety in an environment that was constantly evolving and fraught with potential hazards.

Defence, civil defence and voluntary organizations:

In the Gjerdrum crisis management, the operational environment for Defence, Civil Defence, and voluntary organizations was marked by a need for high-level coordination, technical expertise, and adaptability. The Norwegian Joint Headquarters and various military squadrons, including the 333 Squadron Andøya, 337 Squadron Rygge, and 330 Squadron, along with the Norwegian Special Operations Forces, played a significant role. Simultaneously, Civil Defence and voluntary organizations operated within a structured yet collaborative framework. Volunteers, organized under the Voluntary Organizations' Rescue Professional Forum (JRCC, 2021, p. 26), worked within a system that balanced their autonomy with the need for professional coordination. This required adaptability, teamwork, and adherence to established command structures and protocols to ensure safety and effective response. The involvement of multiple agencies, including local authorities and emergency services, required clear and efficient communication to align efforts and avoid overlap. Furthermore, the Civil Defence needed to be particularly flexible, adjusting strategies and tactics in response to evolving conditions. In all these groups, the operational environment was characterized by logistical complexities and the challenge of rapidly deploying personnel and technology. This environment required seamless coordination among a wide range of specialized groups, emphasizing the complexity and multifaceted nature of response efforts in the Gjerdrum crisis.

System 2

In the Gjerdrum crisis, the coordination role of System 2, led by the Norwegian Directorate for Civil Protection and Emergency Planning (DSB), was crucial as per Beer's Viable System Model. Beer (1985) described this coordination function as 'anti-oscillatory', a concept that was evident in DSB's approach. The regulatory center, represented by System 2, functions to dampen oscillations – that is, to prevent fluctuations and instability in the system's overall response. DSB's role went beyond merely issuing centralized rules; it also involved regulating the interactions among System 1 entities to maintain stability and coherence in the response. This 'anti-oscillatory' function ensured that despite the decentralized nature of the operations, there was a harmonious balance, preventing any counterproductive oscillations in the system's performance. Thus, DSB's operational environment was characterized not only by its coordination and cohesion but also by its crucial role in maintaining operational stability amidst a dynamic and potentially volatile crisis scenario.

System 3

In response to the Gjerdrum landslide, NVE's role was pivotal in dynamically adapting to the evolving nature of the disaster. They worked closely with the Incident Commander's Command Post (IL-KO), continuously assessing the changing risks associated with entering the landslide area. This evolving situation required NVE to make crucial, real-time decisions, such as deeming rescue efforts unacceptable at certain points due to heightened safety concerns. The dynamic operational environment was further characterized by NVE's response on the evening of December 30th, when they identified an expanded unsafe area and issued SMS alerts to several households, reflecting their proactive approach in a rapidly shifting scenario. The Norwegian Communications Authority (NCA) supported these efforts by ensuring that vital communication channels were maintained, crucial in the face of the rapidly changing landscape and the unpredictable nature of the landslide.

*System 3**

In the Gjerdrum crisis, System 3* faced a highly dynamic and complex operational environment, with NVE and NGI at the forefront of monitoring and auditing. Their role involved continuously adapting to the rapidly changing conditions of the landslide. NVE and NGI's expertise was crucial in assessing ground conditions and advising on potential areas of risk, which required constant updating as the situation evolved. The dynamic nature of the crisis necessitated quick, informed

decision-making, particularly in identifying new risk areas and advising on evacuation zones. This process was challenging due to the unpredictable movement of the landslide masses and the evolving understanding of the affected zones. Moreover, the ambiguity about NVE's role within the IL-KO added to the operational complexity, requiring them to repeatedly clarify their responsibilities. The operational environment for System 3* was marked by its need to manage and respond to these evolving risks and uncertainties, exemplifying the critical need for adaptability and accurate, real-time information in managing such a complex crisis scenario.

System 4

In the Gjerdrum landslide crisis, System 4's focus on strategic direction and long-term planning involved crucial actors such as the Norwegian Geotechnical Institute, Multiconsult, and the County Governor. These entities were tasked with assessing immediate impacts and forecasting future risks, including secondary landslides and community needs. Rapid integration of evolving information was essential for their dynamic decision-making, addressing immediate crisis management and preparing for future challenges. Their efforts, including the County Governor's role in regional coordination and policy guidance, encompassed developing strategies for infrastructure reinforcement, adjusting land-use policies, and enhancing community preparedness. This approach in System 4 adeptly balanced immediate crisis responses with a resilient, long-term strategic framework, incorporating the County Governor's pivotal role in shaping regional strategies.

System 5

System 5 guided by the Ministry of Justice and Public Security, aimed to provide clarity on the overall direction and purpose of the SAR crisis management system. It was tasked with designing conditions for organizational effectiveness, which involved critical decision-making following extensive discussions within the Intelligence and Control functions. The need for selectivity in information reception was addressed through interactions with other functions, including The Norwegian Directorate of Health. The close interconnectedness of these functions was crucial in ensuring that emerging issues were thoroughly examined and aligned before reaching the Policy function. This complexity underscored the importance of well-structured decision-making processes and organizational dynamics in effectively managing the Gjerdrum crisis.

4.2. The structural diagnostics

In complex systems, the interconnections between subsystems can present structural challenges (Hermelin et al., 2020). These challenges often arise from either overly formal or excessively informal communication protocols. Rigid communication within the coordination subsystem (System 2) can impede timely decision-making, while ad-hoc communication can lead to confusion and misalignment. This study focuses on the structural challenges inherent in the SAR system's evolving dynamics. Integrating temporal aspects into the VSM, such as feedback loops (Fig. 5), interorganizational collaboration, and decision and implementation delays, adds complexity to the operational environment. A respondent (P1) directly addresses this challenge:

[…] So, there were challenges, especially in the beginning, where the municipal and state authorities didn't quite understand how to resolve the situation afterward. As mentioned, it was the municipality that was on its knees, not entirely, but in creating and finding resources to take over and figure out how to involve other actors instead of state resources. It took some time; it took 10 days. […] Yes, there was our own dialogue with the district chief of the Home Guard HV 02 and the civil defense after they took over. But we agreed that the civil defense would assist in a phase until the municipality and the state governor had things in place […].

The situation explained by P1 shows the complexity of coordinating across multiple agencies and government levels. The crisis also underscores problems in resource allocation and management, with an over-reliance on municipal resources and unclear protocols for involving state actors. Within the same context, however, we find another example ending with a successful result. A relevant example is the air rescue operation described by JRCC (2021, p.55). The operation exemplified the importance of temporal dynamics in crisis management, as conditions rapidly evolve, demanding quick adaptation and real-time decision-making. This operation, involving three helicopters - the Rygge rescue helicopter and two police helicopters - was carried out independently, without direct oversight from the on-site command. This autonomous and well-coordinated effort, crucial in the early and critical hours of the crisis, underscores the importance of timely and decisive action in emergency situations. The teams' ability to rapidly adapt and respond effectively without immediate guidance highlights the vital role of swift, coordinated efforts in managing the temporal dynamics of crisis situations.

The establishment of two IL-KOs, with the second being the 'drifts-KO' (DK), exemplifies dynamic crisis management. The forward KO's swift setup near the avalanche for essential logistics mirrors the DK's focus on rapid response and initial assessment (Grahl-Jacobsen et al., 2021, p. 40; JRCC, 2021, p. 9). Simultaneously, the operational KO caters to changing needs like telecommunications and animal care, reflecting the DK's adaptability over time. This approach showcases the DK's strength in temporal management, blending immediate response with progressive strategy in emergencies. However, the use of multiple operations centers presented coordination difficulties and introduced the potential for inefficiencies in the rescue operation:

> *There were at times many actors and individuals involved in the decision-making processes in the IL-KOs. This resulted in time consumption that was challenging in a time-critical rescue operation. (*JRCC, 2021, p. 9*)*

Furthermore, informants noted that the concept of an operation center was unfamiliar to the municipality, further complicating coordination efforts:

> *It was the police who established the operation center, a function that we adopted. We took over the operations team that was initially set up to lighten the workload of the managers during the start-up phase. However, this model was completely unfamiliar to us. We lacked both the manpower and expertise to effectively run the operations center. (M2)*

The findings also revealed a misalignment between the tasks performed and the standard procedures. P2 explained that, despite the smooth collaboration between the organizations involved in the Gjerdrum landslide, the informants reported that tensions arose between the police and the municipality. The police were responsible for the initial response phase, which included search and evacuation operations, and they are well trained to handle high-pressure situations. However, the municipalities have different organizational cultures and lack the capacity and expertise to deal with such an unexpected event. As such, they heavily relied on the police and the operations leader to guide them through the situation. Eventually, the police completed their tasks and intended to withdraw, but the municipalities expected further assistance from them. This indicates a structural challenge within the system and suggests a lack of adherence to prescribed protocols. In addition, task prioritization and interconnections were found to be either too rigid or too flexible in several instances, leading to inefficiencies and misalignments within the overall structure (see Table 4).

The findings related to structural challenges address the complexity introduced by the temporal aspects of the VSM. Factors such as feedback loops, decision delays, and adaptability were identified as contributing to the challenges faced in the operational environment. Understanding and managing these temporal dynamics became crucial for effective structural diagnostics.

4.3. The functional diagnostics

Functional problems arise when some subsystems in the organization are not functioning effectively to achieve their objectives. For example,

Table 4
The structural diagnostics and pathologies.

The VSM diagnostic systems	Pathologies	Key findings
Task complexity (S1)	Lack of vertical partitioning	- Tasks were undertaken in ways that did not align with those expressed in the standard procedures. The municipality was struggling to rapidly transition into a crisis organization in a short period. Due to limited resources and capacity in managing daily operations and handling challenging situations, there were challenges in transitioning into a crisis response organization. Inadequate evacuation management, healthcare facility adaptation, and ongoing health service support by the municipality. The dual IL-KO model, with the rapid deployment of a forward KO for logistics and a dynamic 'drifts-KO' (DK) for evolving needs.
Multi-organizational response activities (S1)	Entangled ethos	- Multiple actors with different criteria were involved, including the police and the municipality, particularly with regard to flight restrictions in the affected area. This response also included the participation of non-governmental organizations and social volunteers. The home guard had a contingency agreement with the state but not with the municipalities. Therefore, according to their contract, they were prevented from contributing to the municipality.
Inefficient administrative capacity (S5)	Lack of recursion at the top level	- The municipality of Gjerdrum did not address the relevant incidents, especially the realistic scenarios. The municipality planned to carry out three exercises in the near future in the areas of nuclear events, landslide, and pandemic, but it did not have time to carry out this before the COVID-19 pandemic started. There was a lack of overall leadership within the municipality, which hindered the organization of the transport and evacuation processes. As a result, the municipality had to reach out to private companies for assistance. The Gjerdrum municipality had not practiced its emergency plan as often as required by regulations.
Insufficient thoroughness and relevance of the exercises (S1)	Lack of consensus in the decision-making style	- In the day-to-day operations of a municipality, decision-making typically involves strong management anchoring and broad participation. However, within the police department, decisions were often made ad-hoc and with limited information.
Insufficient infrastructure and planning (S2–S5)	Lack of overall planning and preparedness	- The lack of an operations room in the municipality was identified as a critical issue as it hindered the ability to observe live operations. According to the informants, this is not a common situation in other similarly sized municipalities. The county governor stated that the Gjerdrum municipality failed to carry out the necessary exercises, particularly realistic scenarios, which was evident in the municipality's inadequate implementation measures in response to signals that indicated areas prone to landslides. Consequently, there were insufficient connections between different levels of the system's recursion. There was a management vacuum after the rescue operation ended.

if the operations subsystem (System 1) is not running efficiently, it may result in delays, errors, and low-quality output. Identifying functional problems can allow for the determination of which subsystems are underperforming and the underlying reasons behind this underperformance, thereby enabling corrective measures to be implemented. Table 5 addresses some of the functional challenges identified in the study's findings.

4.4. The communicational diagnostics and information bottlenecks

Overloaded or inappropriate communication channels can cause problems. If System 4 lacks timely data, decision-making may suffer. Identifying these problems helps to optimize channels and improve information flow. However, this study found instances of successful communication during the response operations as there was regular and informal communication as well as information exchanges, which promoted collaboration between the actors involved. Daily interactions occurred, for example, between the county governor and police through rescue management, and the police liaison worked closely with the Gjerdrum municipality. An interviewee from The Norwegian Directorate for Civil Protection and Emergency Planning, D1, highlighted the importance of preexisting relationships in overcoming challenges:

> *The importance of having established relationships with the people you are working with in such scenarios cannot be overstated. We already had that connection [to COVID-19]. And, at least at the agency level, I believe that this made things considerably easier.*

However, we also identified several challenges, which are outlined in Table 6.

5. Discussion and implications of the results

Crisis response systems' viability depends on their adaptability, communication efficacy, and balanced decision-making structures. Rapid adaptation to changes and effective communication are vital. However, if central control and local autonomy disrupt the system's cohesiveness, as per the "Law of Cohesiveness" (Beer, 1984, p. xii),

Table 5
The Functional Diagnostics and Pathologies.

The VSM diagnostic systems	Pathologies	Key findings
Negative synergy and conflicting goals between the five subsystems	Lack of consensus on areas of responsibility	- The municipality and its media department threatened the police, urging them to publicly state that they would not provide assistance. They also attempted to impose flight restrictions and similar measures. The responsibility for coordinating and leading the air effort in the land rescue operations was unclear.
Underdeveloped primary activities in S1	Limitations in organizational cooperation	- The civil defense had a contingency agreement with the state but lacked one with the municipalities. Consequently, their contract prevented them from providing assistance to the municipality. The weak coordination system led to a shift in focus from adaptive activities to immediate crisis response tasks. The original municipality contingency plans did not account for the extent of the landslide, highlighting its lack of preparedness. Despite attempts to extend the assistance of the home guard, home guard were unable to do so due to a lack of formal authorization. The municipality was not fully prepared to assume responsibility when the police concluded the rescue operation.
Underestimated need for authorization of coordination activities (S2)	Lack of authority to make ad-hoc decisions	- The presence of a liaison occasionally led to delays in the decision-making process. The team leader at the local rescue centers did not have authority over people outside of their immediate team. During the rescue operations, there was no pre-existing agreement between the leader and the active emergency response teams on the ground.
Inefficient operational capacity (S1)	Lack of adequate resources	- Specific equipment that the municipality did not have at the time, such as walkie-talkies, was needed.

Table 6
The communicational diagnostics and pathologies.

The VSM diagnostic systems	Pathologies	Key findings
S1–S2 information flow	Unclear communication	- The widespread use of abbreviations caused great confusion in local governments, especially during council meetings in which representatives from different sectors encountered myriad condensed terms.
Weakness in System 3*	Muted algedonic channel	- Challenges were encountered in terms of maintaining and ensuring the effectiveness of internal communication and decision-making. The lack of proper oversight and coordination within S1 hindered the timely exchange of information and coordination of actions.
Insufficient communication capacity (S1–S5)	Lack of internal control	- Challenges were encountered in the communication process during the initial stages as it was marked by multiple conflicting instructions. For example, the extensive use of abbreviations led to significant confusion in local governments, particularly during council meetings as representatives from different sectors encountered a range of abbreviated terms.
Weaknesses in Systems S2 and 3*	Fragmented information systems	- The capacity of the emergency network was inadequate during the most critical moments. As a result of multiple response organizations being involved, real-time communication became challenging and resulted in increased coordination complexity.

viability is compromised. During Gjerdrum's crisis response operations, various pathologies (see Section 4) emerged due to different subsystems, such as the municipality, police, and healthcare authorities operating independently and overlooking the need for comprehensive coherence and coordination. These pathologies will be further elaborated on below.

5.1. *The functionality of interorganizational collaboration*

The functionality of interorganizational collaboration depends on the contextual issues embedded in the situation at hand as well as ensuring a balance between control and flexibility in coordinated emergency response. As highlighted by Boersma et al. (2014), as the severity of the incident increases, the operating conditions become more unpredictable, urgency intensifies, and the scale and scope of the incident exceed the initial responding organizations' capabilities. Consequently, the tension between goals, rules, and practical demands remains the principal challenge for emergency responders working in intricate and dynamic conditions that are a result of extreme events. The evaluation report highlighted the following: "Management's challenge during emergency response efforts is that incidents will be dynamic and complex, with multiple concurrent events occurring over a large geographical area. There will be many tasks to be carried out simultaneously, with various actors making decisions" (Grahl-Jacobsen et al., 2021, p. 15).

The situation in Gjerdrum posed considerable challenges for the existing emergency response system as it required immediate coordinated action from multiple entities. The coordination methods varied from a hierarchical incident command structure to informal networks of individuals. However, managing the unique combination of elements in the crisis led to confusion and delays in organizations' collaborative efforts (Leonard, 1993). Furthermore, the decentralized decision-making and crisis management structure created challenges in the sense-making process. This difficulty intensifies when organizations have to assume roles for which they are not trained nor experienced (Rankin et al., 2013):

> *When command lines are extensive and long, it can be difficult to establish a shared understanding of the mission, challenges, and solutions. On the contrary, short command lines often facilitate effective cooperation and foster a common understanding of the situation, serving as a success factor. (*Grahl-Jacobsen et al., 2021, p. 54*)*

Our findings highlight a significant number of tasks performed by various actors during crisis management operations. These tasks require prioritization and coordination to ensure the functionality of operational responses. As the first level (S1) operational units are somewhat independent, the system requires methods that create synergy among these units to mitigate the impacts of counterproductive self-interest (Devine, 2005). However, poorly identified roles and responsibilities along with inadequate connections between organizations within System 5 (see Fig. 5) at different recursion levels negatively affected the functionality of the crisis management system:

> *In addition to the rescue operations, numerous other tasks arose. These included managing farms with hundreds of animals within the evacuated zone, implementing infrastructure improvements such as water and road systems, and retrieving crucial assets from evacuated buildings…… These tasks were critical for a municipality, but for us in a rescue operation, they were subordinated. (P2)*

Limitations in organizational cooperation also impacted the functionality of the SAR system and hindered the development of trust, which is crucial for effective collaboration among different organizations (Roud et al., 2020). These limitations may inhibit organizations from understanding each other's priorities, communicating effectively, and use of sector-specific terminology, resulting in challenges in achieving effective cooperation and leading to negative synergy, such as the flight restrictions that were implemented over the landslide area: "The municipality and their media department started threatening the police that they should declare in the media… that the police would not help them and arranged a flight restriction and such" (P1).

There was also a lack of mutual understanding and familiarity between the organizations in terms of social security, crisis management, and cooperation. This could have hindered interaction and cooperative behavior through the reciprocity principle, resulting in an uncomfortable social situation (Falk & Fischbacher, 2006). Additionally, our findings confirm that the actors involved in the crisis response operations had a plan in place before the landslide, but it was not clear whether the planning system was coordinated among organizations, including the municipality, home guard, police, and state administrators. Consequently, the involved organizations had control over their own planning but were not aligned with one another. The municipality and the public administrator are known to follow a deliberate and bureaucratic approach to decision-making by relying on objective, fact-based information, while police tend to make decisions quickly and efficiently during emergency situations without the benefit of thorough consideration (Christensen et al., 2018). Despite the importance of following plans and standard procedures in crisis management, it is essential to recognize that uncertainty, time pressures, and increasing consequences require the continuous adjustment of emergency response plans (Boin & Renaud, 2013). These adjustments are crucial for the effective and safe management of new and reshaped threats in highly dynamic and unforeseen scenarios (Boin & Rhinard, 2023; Steen et al., 2023). In Beer's (1984) interpretation, viability is directly associated with purpose and incorporates qualitative measures such as cohesion, identity, and ethos alongside quantitative ones such as duration or headcount. Leonard (1993) stated that "success" in this context is considered a product of "effective action" rather than simply survival.

The informants stated that while they had experience with crisis management from previous events, this experience served as a basis for improvisation in situations in which the plan does not account for the event (Bigley & Roberts, 2001); although all the informants mentioned performing or planning exercises for various types of events, none of them had practiced for the specific situation that occurred in Gjerdrum. While exercises can build trust between organizations and enhance crisis management capacity (Roud, 2020), their effectiveness depends on their relevance. As highlighted in our findings, there may not always be a connection between what is practiced and what happens in real-life situations, which can negatively impact trust between organizations. Therefore, establishing direct communication with people who have decision-making authority rather than relying solely on liaisons was recommended by P2:

> *Liaison is acceptable, but I have noticed that it can create delays. Instead of having a direct link, everything has to go through me first. While it is understandable that the municipality follows this process, I believe it would be beneficial to identify someone with decision-making authority who… you can contact directly, preferably via email, for matters requiring a decision from the police. This would eliminate the need to go through me every time.*

The informants emphasized liaising with businesses, establishing operational centers, and preparing organizations for the withdrawal of rescue services. They recommended creating a specific plan for the transition phase, thereby ensuring organizations' preparedness for coordination and addressing responsibilities after the emergency services leave. Enhancing the operational response system's functionality requires concepts such as "samhandling" (Steen et al., 2022; Steiro & Torgersen, 2018) and "auftragstaktik" (Keithly & Ferris, 1999), which emphasize decentralization and local autonomy in adapting policies and procedures. After the rescue operation, there was a management gap during the transition from the acute phase to normalization. To address this, it is crucial to develop a precrisis transition plan that identifies and prepares personnel for post-crisis leadership roles. This proactive planning will ensure continuity and effective decision-making (Hassel & Cedergren, 2019; Steen et al., 2023).

5.2. The structural characteristics and interconnections between the subsystems

Table 3 highlights the structural issues that challenged the SAR system's viability in terms of responding to the Gjerdrum landslide. Collaborative crisis management can be viewed as a system of systems, with each system representing a crisis response actor (Olsen et al., 2023). Dependencies play an important role in influencing coordination effectiveness and are categorized into two dimensions: vertical, which involves relations between actors at different hierarchical levels of governance, from ministers and directorates to local entities such as municipalities and first responders; and horizontal, which relates to actors who need to coordinate at the same level but lack hierarchical relationships with one another (Boin et al., 2017; Christensen & Lægreid, 2020). Coordination activities (S2) within the VSM facilitate harmonious collaboration and integration of system components (Brocklesby, 2012).

The Gjerdrum crisis response operation involved complex dependencies between actors. The absence of vertical partitioning and top-level recursion (Table 4) resulted in limited resources, conflicting goals, and hindered coordination. This led to insufficient collaboration and integration between the subsystems as well as delays and inconsistencies in the decision-making processes (Hoverstadt, 2020). Similar to other crises, as the operations became more intricate and uncertain, the challenges of coordination intensified and created a demanding environment for effective coordination. Findings indicate that the scale of the operations expanded, encompassing tasks such as managing the landslide, evacuating people from the affected areas, and searching for casualties. For instance, the municipality encountered significant coordination challenges, particularly in managing healthcare and support for vulnerable groups. The frequent relocations of these groups highlighted the logistical and care challenges in temporarily converting a hotel into a functioning care facility, and the limitations in securing sustained

support from neighboring areas (Grahl-Jacobsen et al., 2021, p. 50). This situation underscored the need for better systemic integration and capacity planning within the municipal support framework.

From the perspective of the VSM, coordination plays a vital role in bringing together the various stakeholders that are involved in the development and implementation of effective crisis management strategies for a specific situation. It improves preparation and response by facilitating proactive learning and resource training as well as ensuring organizations and actors' capacities and capabilities to effectively manage future crises. Our findings indicate that crisis response authorities faced significant challenges in achieving cross-sectoral coordination between the various actors that had different cultures and power structures. Additionally, from a structural standpoint, the intertwined ethos and lack of top-level recursion presented difficulties in managing the operations as "significant challenges arise when staff members are replaced or relocated, including inadequate marking and overview of roles" (Grahl-Jacobsen et al., 2021, p. 68).

In the Gjerdrum rescue operation, the primary objective was to rescue and recover as many people as possible. The adoption of the incident command system structure by the municipality helped to align the different subsystems' goals for achieving this objective. The municipality had to undergo a rapid transformation from a rather small administrative unit to a crisis organization, which involved significant changes in tasks, decision-making authority, and decision-making speed. Furthermore, the existing plans were inadequate for dealing with the disaster, which necessitated the development of new routines and a willingness to make swift decisions, even if they needed to be revised later. This adaptive response can be viewed as a "system reset" (Bigley & Roberts, 2001), thereby aligning with the concepts of the VSM. Building on this adaptive foundation, on Friday morning, the operational agility was further exemplified when two USAR teams, supported by a local contractor, engineered an access road to a strategic point near the landslide. This approach facilitated the deployment of innovative solutions such as the use of Styrofoam plates to create a floating pathway over the quick clay, which was up to 10 m deep in certain areas. This floating bridge enabled USAR personnel, including teams from Gothenburg Fire Department and Nedre Romerike Fire and Rescue Service, to safely reach and recover individuals from the partially buried houses. This collaboration and coordination of efforts underscored the municipality's dynamic response to the crisis, ensuring that all sectors operated under a cohesive situational understanding (Grahl-Jacobsen et al., 2021, p. 45).

5.3. Communication and its effect on interorganizational collaboration

Effective communication and information sharing comprise various aspects, including collecting, receiving, sharing, and maintaining communication networks (Olsen et al., 2023). These activities are crucial for effective collaboration. From the perspective of the VSM, communication flows serve as vital links that connect S1 to S5 as they ensure the exchange of information and coordination throughout the system, especially considering the dynamic nature of the operational environment. Effective information flows and communication links are also essential for the government's ability to interpret and make strategic choices during the early stages of a crisis (Boin & Rhinard, 2023). It also directly impacts the level of support that the authorities receive from the public for their crisis initiatives.

Trust is cultivated through effective communication and is the foundation of a viable crisis management system. Failure to communicate decisions effectively can result in diminished public trust in the authorities' handling of the crisis. From the VSM perspective, the intelligence system is responsible for gathering, processing, and conveying information regarding the external environment. This process is challenging:

> *We… relocated people to several hotels, and our goal was to ensure the information was accurate, timely, and empathetic…..… In vulnerable states, people shouldn't be overwhelmed with excessive information: The information should be reiterated, sufficiently clear, and considerate of their circumstances. (M1)*

The communication pathologies (see Table 6) outlined the complications that surfaced when communication channels failed to efficiently manage the required informational influx, resulting in a lack of mutual understanding and collective situational awareness. A fragmented information system also caused a delay in informing the designated fire chief authority about the severity of the situation: "Technical errors prevented the message from reaching the intended recipient. The system's barriers or checks failed to detect this issue before the situation escalated" (Grahl-Jacobsen et al., 2021, p. 40).

These obstacles could impede operational planning, and an evaluation report addressed this challenge: "Challenges related to 'operational planning' are that the planner(s) and the crew at the sharp end have a different understanding of the situation" (Grahl-Jacobsen et al., 2021, p. 49). Consequently, a brigade commander had to be called in as an additional resource to address the situation. By intervening to address this issue, the brigade commander exemplified the function of intelligence and policy (System 4), thus serving as an additional support to bring stability to the crisis. Consequently, the shortcomings in system 3* led to difficulties in forming a unified situational awareness among all parties involved. Moreover, findings shows that the Gjerdrum municipality faced significant challenges in ensuring all residents received timely and accurate information during a crisis. Key issues included covering the diverse information needs of the population, rapid dissemination of evacuation alerts through SMS and voice calls, and the difficulty of providing detailed evacuation maps online:

> *[…] The municipality's mobile alert system, which is based on list-based mobile alerts via SMS and voice calls to landlines, is used in consultation with the police to alert inhabitants who need to evacuate. It eventually becomes clear that not everyone receives the evacuation alert via the municipality's solution. There are also challenges in providing a good map of the evacuation zones to the population on the police's and municipality's websites. (*Grahl-Jacobsen et al., 2021, p. 49*).*

Table 6 labels these issue as muted algedonic signals. In the VSM terminology, algedonic signals are internal channels within a system that allow for instant communication from the bottom to the top of the hierarchy. They serve as triggers for managerial intervention and decision-making that address the issues or opportunities they represent (Leonard & Beer, 1994). In the context of a complex, multi-organizational system like the Gjerdrum crisis response operation's Search and Rescue (SAR), involving numerous stakeholders, the concept of muted signals becomes even more crucial. Ideally, the command and control system would have ensured effective communication of the evacuation message to both residents and relevant authorities. However, the term "muted" indicates that there has been a breakdown in this communication, resulting in delayed or inappropriate responses. Furthermore, in such complex systems, algedonic signals can be muted at any point and within any stakeholder group, which adds to the challenge. This goes beyond the oversimplification often depicted in models like Fig. 5, as the muting of algedonic signals can occur along various paths and involve different stakeholder groups, rather than following a predefined path indicated by a dashed red line in Fig. 5.

However, technical glitches prevented this, exposing a flaw in the municipality's internal communication controls (System 3*), which are supposed to manage routine communication and coordination. This oversight in detecting failures points to a lapse in the coordination mechanisms (System 2), tasked with resolving conflicts and allocating resources effectively. To deal with communication challenges, Gjerdrum municipality received support from various entities, including neighboring municipalities, the county municipality, and the County Governor. Gjerdrum also decided to hire a private consulting firm early

on to help with crisis communication.

As one of our informants reported: "We received signals from the police after a few days, pointing out that the police will withdraw very soon, but we did not know what that meant" (M1). This underscores the necessity for clarity and comprehension to ensure that the response to the situation is effective. Furthermore, our findings suggest that crisis management communicators were supported by crisis and incident management software (CIM). This communication platform enabled the simultaneous sharing of information, alert roles, actions, and decisions with the relevant stakeholders, thereby facilitating the dissemination of information to the public. However, the extensive use of abbreviations, names, and terms that are typical in S1 operations introduced obstacles in the data interpretation process: "The talk groups within the communication system carry identical names, generating confusion both within our team and at the 110-emergency center. The system appears chaotic" (Grahl-Jacobsen et al., 2021, p. 62). Thus, the communication system was viewed as disorderly. Hence, for both simulated and real-world operations, clear language is required for articulating commanders' intentions in crisis management, such as using a standardized approach similar to the Societal Security standard within the ISO/TC-223 framework and the Emergency Data Exchange Language (Gustavsson et al., 2006).

6. Conclusion

The VSM proved to be a robust framework for understanding the complexities of crisis response in a turbulent environment when it was used to examine the viability of Norway's SAR system in response to the Gjerdrum landslide crisis. Through this diagnostic approach, we identified the pathological features that challenged the SAR system's effectiveness and viability, including imbalances, inefficiencies in maintaining internal and external interactions, communication breakdowns, and inefficient resource allocation. These insights clarified the structural challenges within the SAR system and underscored the significance of optimizing interconnections, establishing efficient decision-making processes, and improving communication flows to enhance the overall effectiveness of the SAR. Addressing these issues is crucial for improving the system's performance and preparedness for future crises. Although our analysis specifically focused on landslides, the inherent flexibility of the VSM means that it can be applied to the analysis of other crisis response operations, both at the unit level and the system level. Consequently, our contribution to the crisis management research literature highlights how using the VSM as a methodology and conceptual framework allows for the analysis of collaboration in disaster response efforts.

The emergence of artificial intelligence (AI) presents a promising avenue for analyzing dynamic and structural complexity in conjunction with the VSM: The integration of AI with VSM can offer powerful tools for analyzing, predicting, and optimizing the behavior of complex systems, such as SAR systems, thus enabling more effective decision-making and adaptive responses. This combination of AI and the VSM holds great potential for future research as it addresses the intricate challenges posed by the dynamic and structural complexity in various domains.

CRediT authorship contribution statement

Riana Steen: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Ensieh Roud:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization. **Trude Mikkelrud Torp:** Investigation. **Thor-Arild Hansen:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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