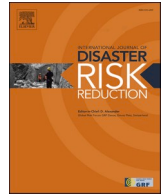




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Resilience in emergency management: Learning from COVID-19 in oil and gas platforms

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ABSTRACT

Emergency management, both in civilian and military context, is regarded as a complex socio-technical system, whose dynamic nature and complexity require a holistic approach. Over time, scholars developed diverse strategies and methods to capture such complexity and effectively design emergency plans for more or less severe disasters scenarios. Nonetheless, planning is not always an omni-comprehensive task, pushing organizations to stretch their adaptive capacities in dynamic and challenging settings.

This manuscript explores such adaptive capacity as put in place by a leading Norwegian organization in providing emergency management solutions, facing unexpected challenges (at the time of the event): handling of Covid-19 infection episodes on offshore oil platforms.

The study, conducted through the Functional Resonance Analysis Method (FRAM) highlights the relevance of organizational learning which allows to handle emergencies by adapting plans to the specific context and by renewing new emergency management procedures derived from lessons learned. The study focuses on three different Covid-19 infection management cases to understand the nuances of actions and emerging adaptations that led to the development of a revised emergency plan, seen again through the lens of FRAM. While the methodological approach refers to Covid-19 infection management, we believe it can be extended into larger crisis management, providing a use case for the applicability of FRAM into emergency management scenarios.

Nomenclature

Acronyms

AC	Authority Coordinator
CIM	Incident & Crisis Management
COS	Chief Of Staff
DSV	Drilling Supervisor
EM	Emergency Management
EMS	Emergency Management System
ER	Emergency Response

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ERM	Emergency Response Manager
ERT	Emergency Response Team
FAL	Professionally Responsible Physician
FRAM	Functional Resonance Analysis Method
HR	Human Resources
HTA	Hierarchical Task Analysis
IC	Information Coordinator
JRRC	Joint Rescue Coordination Centre
LC	Logistics Coordinator
NATO	North Atlantic Treaty Organization
NOFO	Norwegian Clean Seas Association for Operating Companies
O&G	Oil & Gas
OFFB	Operator's Association for Emergency Response
OHS	Offshore Health Services
OSEP	SAR helicopter, Evacuation centre
PC	Personnel Coordinator
PSA	Petroleum Safety Authority
RE	Resilience Engineering
SAR	Search And Rescue
TA	Thematic Analysis
WAD	Work As Done
WAI	Work As Imagined
WM	West Mira
WP	West Phoenix

1. Introduction

Emergencies create challenges for organizations by putting them in settings where they stretch operational boundaries and manifest adaptive capacities [1,2]. However, they also represent a chance for changes in policy reforms, institutional overhaul, and even leadership revival [3,4]. Adaptive capacity and willingness to change are key elements for embracing such learning opportunities [5–7]. Understanding what worked well during the emergency, which aspects of emergency plans were successful, which ones were not put in place, or not even practicable, etc., enhances organizational resilience for future Emergency Response (ER) operations [8]. Learning from emergencies is at the heart of the recovery and mitigation stages in any Emergency Management System (EMS), even though it is not a linear and straightforward process. The actors involved in ER operations might have different priorities, goals, opinions, strategies, and political agendas [9].

Covid-19 has imposed ground-breaking unexpected challenges in everyday life, as well as industrial operations. Accordingly, Emergency Management (EM) operations have to be reconsidered to ensure an effective and safe management of new and reshaped threats in dynamic and unforeseen scenarios [10]. Such dynamicity demands for systemic approaches to study operational practices in terms of actual variability, delve into adaptive practices and to look for systems-wide -rather than localized-solutions [11]. This idea refers to the notion of resilience and Resilience Engineering (RE), i.e. the discipline focused on engineering the ability of acting resiliently in face of both expected and unexpected situations. The topic has been highly debated both in emergency management context [12], and in modern safety management [13].

Accordingly, the research question of this paper can be formulated as follows: *How can we harness the study of adaptive practices in response to Covid-19 emergencies to foster organizational resilience?* To answer this research question, this paper documents learning opportunities following the systematic exploration of adaptive practices as they emerge in a complex socio-technical work domain actioned during ER. This study analyses different actualized organizational resilience aspects in an EM company when handling Covid-19 infection episodes. The research has been contextualized into real operations happened in 2020–2021 performed by a Norwegian company responsible for second line EM in Oil and Gas (O&G) platforms, i.e. OFFB¹ (Operator's Association for Emergency Response). Operations have been modelled using a systems-theoretic approach grounded in RE, i.e. the Functional Resonance Analysis Method (FRAM). The analysis goes beyond documental knowledge, rather incorporating qualitative descriptions of work practices as informed by front-line operators.

The remainder of the paper is organized as follows. Section 2 presents a literature review on main aspects of EM, organizational resilience, and opportunities for learning from crises. This section gives evidence on the need to adopt a systemic perspective for EM, justifying the research dimension of this work. Section 3 details materials and method, while Section 4 proposes three case studies referred to likewise previous Covid-19 emergencies in O&G offshore operations. Section 5 discusses the findings in larger

¹ Operator's Association for Emergency Response (OFFB) is a 2nd line ER organization for O&G operators in Norwegian continental shelf. Details on the company are provided in Section 4.1.

organizational management contexts, and Section 6 lists conclusions and future research directions.

2. Literature review

Despite the unique face of any emergency, universal elements reflect underlying common traits of emergency situations. These elements include hazards that pose an immediate threat to health, safety, security, property, or environment, time pressure and a high level of uncertainties.

EM is regarded as complex socio-technical since it mainly deals with collective sensemaking, team decision making, and coordination among different technical and human agents [12].

2.1. Emergency management

EM systems have been divided into four interwoven stages [14,15], i.e. preparedness, response, recovery, and mitigation:

- The **preparedness** stage focuses on preparing plans and a range of alternatives about future emergencies and operating conditions. Preparedness shall be systematic to establish appropriate emergency measures and functional requirements based on risk analysis and emergency preparedness analysis [16].
- The **response** stage refers to responding adequately to emergencies and minimizing their negative consequences following emergency plans, instructions and operating policies. Nonetheless, due to the operational complexity, emergency managers often respond adapting plans and improvising solutions [17,18]. Here, individual's cognitive ability to extract cues from the environment, and to adopt certain strategies, at particular time and for particular threats, is a crucial part of improvisation. There should be a balance between system's preparedness and individual improvisation [19]. Caution is needed regarding front-line operators' ability to estimate properly inherent risk and vulnerability: improvisation can create a spiral of complexity, where each improvisation may create other unexpected settings, requiring further improvisation up to an escalating lack of control [17].
- Following response, when the situation is considered under control, the **recovery** stage begins. While response has well-defined goals (e.g., save lives, environment and properties), recovery is more fuzzy [20]. The primary objective of recovery is bouncing back to normal operations, by means of interaction and effective coordination [21–23], along with reliable communication [24]. Recovery depends on temporal (pace) and spatial (place) settings [25]. Both temporal (e.g., need for a multi organizational coordination) and spatial (e.g., location of platform and high consequence infectious disease) dimensions make the recovery process complex and time consuming.
- **Mitigation** further extends the recovery stage. It aims preventing emergencies occurrence and mitigating their consequences in case they emerge. It includes those activities undertaken to improve EMS by identifying future risks and reducing vulnerability to identified risks and implement necessary changes and measures. Experiences from response and recovery operations provide updated data that can enhance EMS's capacity building. Lessons learned provide valuable insights to this end. Learning, here, is about how key actors perceive their experience into useful knowledge for dealing with future events. These acquired knowledge could be then used to streamline the ER preparedness (first stage) in terms of reforming contingency plans and training to enhance future resilient responses [26].

The design and application of these stages in modern socio-technical EMS operating in complex environments demands for resilience capacities within the organization [27].

2.2. Organizational resilience

The notion of organizational resilience has been used relatively recently to represent organizational response to both expected and unexpected situations [28]. It can be described by means of three principal dimensions: situation awareness, management of keystone vulnerabilities, and adaptive capacity [29]. Situation awareness measures an organization's understanding of its operating environment, and it includes the ability to identify accurately crises and their consequences. Key vulnerabilities are those elements of an organization that could have a significant impact during crises. Adaptive capacity is instead linked to the organization's ability of making decisions in a timely and appropriate manner in daily routine and during crises. Organizational resilience can be seen as an emergent property related to inherent and adaptive qualities to understand context, reduce vulnerability and restore efficacy following a disruption [30]. In EM literature, this organizational adaptive capacity is frequently contrasted with organizational planning [31]. This latter usually relies on business continuity and disaster recovery plans to respectively deal with short- and long-term restoration [32].

Resilience and planning are not conflicting; they should be rather harmonized via a continuous review of past events, identifying recurring themes to foster intra-organization and inter-organization learning opportunities [33], also in cross-domain settings [34]. While planning is more static, i.e. about preventive measures to minimize threats probability and reduce impacts; resilience is more dynamic about managing unexpected disruptions and minimize the response and recovery time [35,36]. Accordingly, joint planning-adaptation efforts are required to properly manage interconnectivity among different infrastructures [37]. The same observation has been raised with respect to developing, disseminating, communicating and implementing disaster plans [38]. Even more recently, the Covid-19 pandemic scenario created opportunities for the same needs. From the examination of response by the English National Health System to Covid-19 crisis, the challenges organizations (both enterprises and public institutions) were and still are subjected to have been highlighted [39]. It has been argued how such a low-chance high-impact event require huge organizational improvisation besides basic planning: increasing autonomy, maintaining structure and creating a shared understanding [17]. By increasing autonomy, leaders allow delocalizing decision rights and encouraging spontaneous actions by front-line operators, trusting

expertise and local information [28]. This setting does not imply the abandonment of structure with clear lines of communication and coordination: it is more about loosening traditional command and control to foster a shared understanding of the situation at hand [17].

Understanding how planning and resilience are set is instrumental for crisis-induced learning, i.e. the organizational purposeful efforts, triggered by a crisis event that lead to new understanding and behaviour [40]. More formally, crisis induced learning spans between a cognitive perspective, i.e. acquiring new knowledge and understanding, and a behavioural perspective, i.e. transposing the acquired knowledge and understanding into improved organizational actions [41]. About the behavioural perspective, single-loop and double-loop learning cycles can be established [42]. The former refers to the correction of practices within the existing policy paths and organizational plans, without changing core beliefs and fundamental rules of the organization. On the other hand, double loop learning aims at resolving incompatible organizational behaviours by setting new priorities and weightings of plans, or by restructuring the norms themselves together with the associated practices or assumptions.

2.3. On the need for systemic approaches

With the aim of ensuring high EMS resilience, and effective single-loop and double-loop crisis-induced learning at organizational level, a systemic perspective should be set when studying past events and revising existing plans.

Aside from using advanced technology in EM operations (e.g., integrated information management system) [43], scholars developed strategies and methods to study socio-technical systems' dynamic nature and complexity, (e.g.) the Dynamic Observe, Orient, Decide, and Act (Dooda loop) approach [44], or the Styrel approach [45]. Learning from the field of safety management, EMS can embrace a systemic perspective and take advantage of modern analytical methods, too. Frequently interpreted as a core method within RE, the FRAM [46] represents a systems-wide modelling tool particularly helpful to deal with socio-technical aspects from a systems-theoretic perspective, including EM operations [47]. This assumption has been documented in a recent research dealing with accident analyses of O&G EMS [48]. Similarly, applications on management practices through the FRAM in emergency response can be retrieved in several case studies, (e.g.) a use case in the Brazilian Environmental Defense Centers (EDCs) [49], on offshore lifting operations [50], or a petrochemical company [51].

From an EMS perspective, Covid-19 adds another dimension of criticalities to well-established procedures, one that demands for high levels of organizational resilience. While FRAM has been used to model several types of socio-technical complexities [47], it has been adopted to a limited scope in Covid-19 management practices, especially when restricted to O&G EM systems. Nonetheless, a recent case study of a Covid-19 incident [52] in a floating oil rig in Norway at the North Sea and related ER operation highlights how the key to a successful EM operation lies in coordination and improvisation, openness, cooperation, and trusting communication between actors. Organizations involved into an emergency need to establish an open strategy for sharing information in order to build situation awareness, and to meet communication and coordination challenges.

On this consciousness, with the intention to explore systems-theoretic possibilities to model EMS, the current paper proposes FRAM as a method for developing a systematic understanding of adaptive practices, modelling planning and resilient behaviours and ultimately supporting crisis-induced learning.

3. Method

The FRAM analysis has been built through a triangulation of qualitative approaches, including document and reports analysis and focus groups. Three Covid-19 cases, happened on the platforms offshore during 2020–2021, have been studied through FRAM models. These latter allowed obtaining an in-depth picture of actual operations and served as a basis to generate systemic recommendations. Moreover, the analysis served as a support for a fourth FRAM model, developed to follow the migration of the emergent adaptive capacities into organizational planning following the OFFB's procedure established in the aftermath of the three Covid episodes.

3.1. Data gathering

Data were gathered from several sources to create a systemic picture of each case:

- Internal documents and procedures related to EM were collected from OFFB's archive, including the "Plan for management of Covid-19-related incidents" [53], from which we elaborated the fourth FRAM model.
- Reports, related to the handling of the three different Covid-19 cases, were acquired from CIM (Incident & Crisis Management) tool. CIM is an electronic crisis handling tool, which gives the 2nd line OFFB's members updated information useful to have a common operating picture of the situation. Through CIM, every member of the Emergency Response Team (ERT) shares the information in their possession, supporting team's situational awareness.
- Finally, we organized five digital focus groups (through video-conferencing tools) with the OFFB's team members, and especially with the team member who held the OFFB's Emergency Response Manager (ERM) role during the first of the Covid-19 cases. Knowledge exchange during the focus groups was favoured by ethnographic research principles, since one of the authors had a sabbatical year working in OFFB. This knowledge allows understanding the working environment and to realizing the actual organizational orchestration during each crisis event.

Thanks to the several data sources utilized, we were able to reconstruct the incidents in the three different case studies and then focus on the OFFB's involvement, within a broader context that saw a multiplicity of stakeholders.

3.2. Data analysis

The internal documents and procedures related to EM were analysed in order to acquire a culture of the company's *modus operandi* and to elaborate on organizational planning, i.e. a Work as Imagined (WAI) model of the OFFB's EM.

The CIM tool reports were firstly analysed recurring to Thematic Analysis (TA) [54], following its most commonly used steps: familiarization, generating codes, generating themes, reviewing themes, defining and naming themes, creating the report. Afterwards, a Hierarchical Task Analysis (HTA) was performed to group the information into tasks based on a hierarchical nature.

As a result of these analyses, some questions were devised to draw up a semi-structured guide for interviews and to facilitate interactions during focus groups. Thanks to the ERM's support during these virtual meetings, we gained an in-depth understanding of what happened during the three cases, defining roles and functions for the actors involved and complementing the HTA results. These actions made possible to elaborate the three FRAM models related to the management of the three Covid-19 cases that occurred on the platforms offshore. In other words, at this stage the adaptive capacities in action emerged in three different representations, i.e. three Work As Done (WAD) models, one per each case.

3.3. FRAM

The core method of the paper is the FRAM, whose principles and building steps are describes in sections 3.3.1-3.3.2.

3.3.1. FRAM principles

FRAM relies on four principles aligned to organizational resilience and RE: equivalence of successes and failures; approximate adjustments, emergence, functional resonance. These principles are relevant for modern EMSs, as proved by the use cases already mentioned in section 2, with specific reference to the O&G sector.

– Equivalence of successes and failures

Despite common opinion, for actions played by individuals and organizations there is an equivalence of successes and failures. RE recognizes that individuals and organizations must adjust to the current conditions in all the activities they perform. Since information, time and resources are limited, these adjustments can only be approximate. Therefore, on one hand success is related to the ability of organizations or individuals to correctly make these adjustments and to anticipate risks before failures occur. On the other hand, failure is due to the permanent or temporary absence of that ability. The aim of RE is to strengthen that ability, rather than just to avoid or eliminate failures.

– Approximate adjustments

As previously acknowledged, adjustments can only be approximate. Accordingly, performance variability exists in what individuals or organization do. Performance variability, which is inevitable, ubiquitous, and necessary, constitutes both the reason why everyday work is safe and effective and why things sometimes go wrong and most of the time go well.

– Emergence

The variability of a single activity is rarely large enough to be the cause of an accident or even to constitute a systemic visible malfunction. Instead, variability from multiple functions may combine in unexpected ways, leading to consequences that are disproportionately large, hence producing non-linear effects. Both failures and normal performance are emergent rather than resultant phenomena. Socio-technical systems change and develop in response to conditions and demands, therefore it is impossible to know all the couplings in the system, hence impossible to anticipate more than the regular events.

– Functional resonance

The performance variability of a single function can be amplified by the combined variability of other functions referred to the

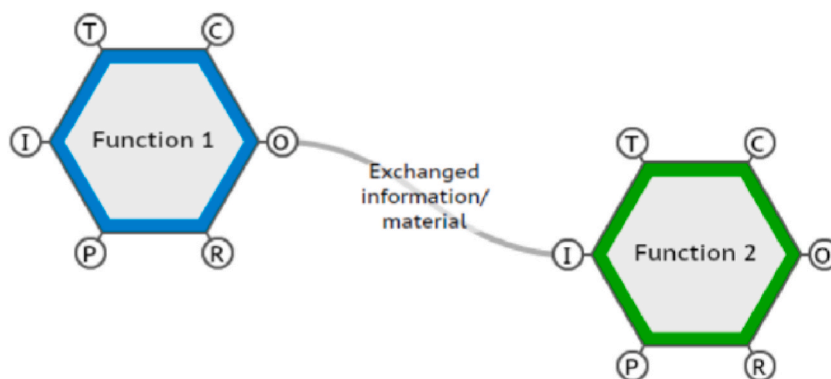


Fig. 1. An example of a trivial FRAM model with two functions and information/material exchange. I: input, O: output, P: precondition, R: resource, C: control, T: time.

same socio-technical system. This feature goes by the name of functional resonance, i.e. the detectable signal that emerges from the unintended combination of the variability of many signals.

3.3.2. FRAM steps

Taking the above-mentioned principles, the traditional four buildings steps of FRAM has been followed in this research [46].

- Step 1: identify and describe the essential system functions.

FRAM describes a complex socio-technical system following a functional perspective, where each function refers to tasks or activities required to produce a certain outcome. There are three types of functions: technological, human, and organizational functions. Each function can be described through six fundamental aspects: Input (I), Precondition (P), Resource (R), Output (O), Control (C), Time (T), graphically represented at the corner of a hexagon, the core element of a FRAM model (see Fig. 1).

In particular, Input is what activates or starts a function and/or that is used or transformed by the function to produce the output. Preconditions refer to those conditions to be satisfied before a function can be actually carried out. Resource is something that is needed or consumed when the function is active. Control is what supervises, regulates, or monitors the function such as guidelines, regulations, or even social expectations. Time refers to the temporal constraints on the function such as duration and starting point. Output is the outcome of a function, the state change or its result.

Function identification has been linked to the results of the HTA based on knowledge triangulation (documents, CIM, focus groups). Each function interacts with others through one or more of their aspects. Interactions connect functions together to form a FRAM net.

- Step 2: identify the actual or potential variabilities between functions.

The performance variability of a function can be categorized in terms of its origin, endogenous variability, exogenous variability, and/or interaction variability, and characterized by different phenotypes (e.g. timing, precision, speed, distance, sequence, duration). Each function of each FRAM model has been studied in terms of their variability to understand where underlying criticalities may reside.

- Step 3: analyse the aggregation of variability.

In a FRAM model, the Output of a function interacts or “couples” with other functions. The output of an upstream function may vary and then transfer the variability to its downstream function(s). Since the aggregation of these variabilities may cause functional resonance in the system, leading to an undesired outcome, all upstream/downstream interactions must be studied in terms of timing and precision. This analysis allows to map events that have already happened (favouring crisis-induced learning), but also to explore other varieties of the work domain, such as worst-case scenarios.

- Step 4: propose ways to manage variability.

This last step aims at mapping what should be the most effective strategies to manage, rather than simply reducing, functional variability. Since this research aims at understanding adaptive practices in an EM company on handling Covid-19 infection episodes, this fourth step is intended to foster organizational learning, rather than simply reinforcing prescribed tasks.

3.4. Operationalizing the FRAM

The theoretical framework based on the four stages (preparedness, response, recovery and mitigation) usually described in EMSs has been rearranged in its operational terms to meet the terminology used by OFFB experts and procedures for Covid-19 infection management. At this stage, we can distinguish four different phases: mobilization, alert, combat, normalization.

For the sake of clarity, Fig. 2 represents graphically the relationship between these four operational phases and the four traditional stages of EM. While there is a major overlapping between preparedness and mobilization, the other phases are usually divided among two steps. On the other hand, this operational categorization allows building a FRAM analysis into a multi-layered framework, one per each phase [48].

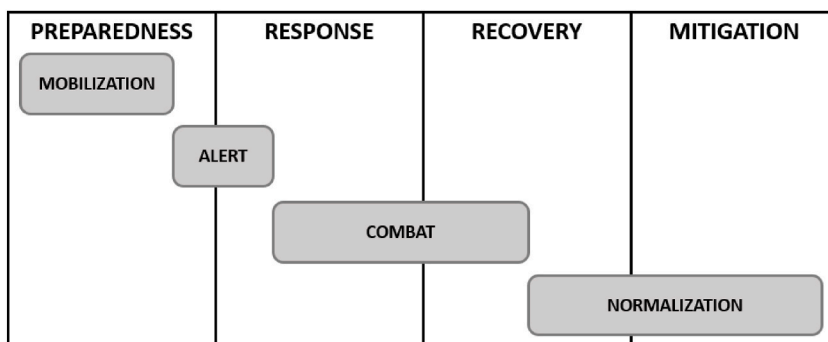


Fig. 2. Relation between traditional elements of EM and the operative phases in place by the company under analysis.

From the afore-mentioned analysis, repeated for each case of Covid-19 that occurred, three different FRAM models were developed, referring to the three different episodes, as shown schematically in Fig. 3. In the first case, given the complexity of the situation (first offshore Covid-19 infection case), we decided to use Time (one of the six aspects of a FRAM function) also as a segmentation variable for the analysis. While time during any emergency spans over a continuum, four different time moments have been identified in line with OFFB’s four operational phases to reduce the analytical complexity of a single large-scale FRAM model. This multi-layer modelling choice has been previously successfully applied in the EM context [48].

Thanks to the crisis-induced learning by OFFB during this first case, the management of the other two Covid-19 infection episodes was instead much less burdensome, without activating all the steps of four phases EMS. Accordingly, a single FRAM layer was used to model each case. It can be noted how this modelling process can be generalized to any Covid-19 infection case, or any other emergency episode: starting from a certain number of specific historic cases to the definition of organizational plans (Fig. 3).

More specifically, to study the management of the first case of infection from Covid-19, we developed a FRAM WAD model of what had happened from a procedural point of view. This model extends the internal plans and procedures (WAI) for the EM.

Following crisis-induced learning from the three episodes, a new procedure for Covid-19 infection management was developed. This latter was modelled via FRAM (in this case, the model embraces a WAI perspective) to exploit the importance of studying adaptive practices to enhance organizational planning.

4. Case studies

In the following sections (cf. sections 4.2, 4.3, 4.4), three different cases are described as for the respective emergencies managed by OFFB. However, to fully understand the cases, we briefly introduce OFFB (section 4.1) as an organization for EM, explaining its mission, responsibilities, functions, and main roles.

4.1. Operator’s Association for Emergency Response organization (OFFB)

OFFB is a 2nd line ER organization for O&G operators in Norwegian continental shelf. Its core business is to manage, maintain and be responsible for the handling of several 2nd line ER activities, utilized by many O&G operating companies. Its main tasks involve responding to incidents that may have an impact on the people, environment and material assets through operations and providing proactive support to the 1st line ER organization to minimize the consequences of the emerging situation. The 2nd line ER also includes the communication with media sources and Next-of-Kin. Although OFFB acts as a 2nd line ER management, the operating companies have the overall responsibility for effective ER in Norway.

Looking at organizational planning, OFFB resembles the NATO joint staff functions [55]: besides ERM, which is responsible for the emergency handling as a whole, there are five other experts who assist entire ER operations, on a rotating duty. ERM has to

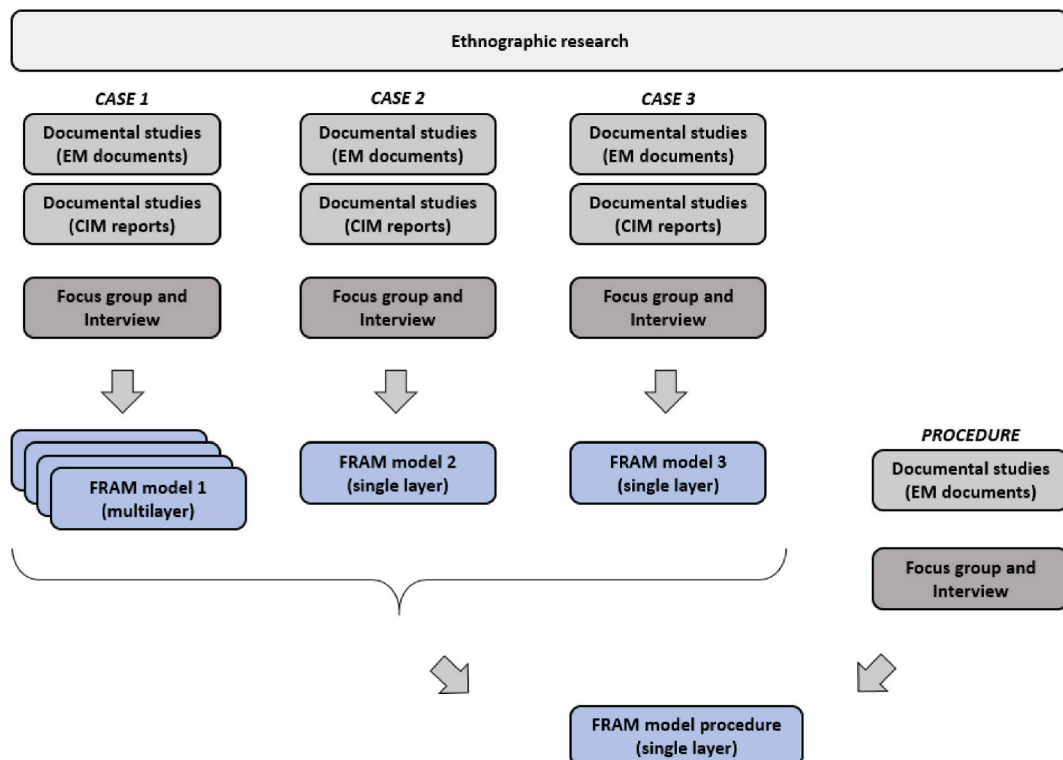


Fig. 3. Outline of the research approach.

mobilize/notify of ERT, perform the initial notification to the Joint Rescue Coordination Centre (JRCC), the 3rd line ER organization (operators), as well as the OFFB's managing director. The ERM has also financial authority to implement any actions deemed necessary to manage an incident. The Chief of Staff (COS) is responsible for initiating mobilization and notification of ERT and the rig owner. COS's tasks are mainly coordination of the ERT and conducting situational awareness with the ERT. The Logistics Coordinator (LC) is responsible for initiating mobilization and notification of the JRCC, the helicopter and shipping operators, supply base (e.g., Logbase Florø) and the logistics suppliers. The Authority Coordinator (AC) is responsible for initiating mobilization and notification of the PSA, Police, and the Norwegian Clean Seas Association for Operating Companies (NOFO). The Personnel Coordinator (PC) has main responsibility for initiating mobilization and notification of the On-Call Physician, contingency physician, Next of Kin Call centre, operator HR representative and the rig owner HR representative. Finally, the Information Coordinator (IC) is responsible for initiating mobilization and notification of the media response team leader for the operators, and the liaison representative from the rig owner. IC is also responsible for notification and interactions with contractors.

4.2. Case 1

From Saturday August 1, 2020 to Thursday 13th of August, the first Covid-19 related event was experienced at West Phoenix (WP) rig, which drilled wells for the oil company Neptune Energy on the Fenja field in the Norwegian Sea.

4.2.1. Event summary

On August 2020, 1st an oil worker from the WP rig was tested positive for Covid-19 at Molde hospital in Kristiansund. There was no suspicion of a Covid-19 infection offshore and 126 people were left on the rig. In the following twelve days, three new cases of infection were detected by extensive testing with a quick test machine on board and through tests sent to the Molde hospital. A total of 46 people were quarantined on the rig as close contacts, while 15 people without safety critical duties on board were sent to the oil company's quarantine hotel on shore.

A wide range of stakeholders - both individuals, groups and organizations - were indirectly or directly affected by the incident and needed information, follow-up and coordination. WP's 1st line ER managed the situation at the tactical level, OFFB 2nd line at the operational level and Neptune Energy's 3rd line at the strategic one. Kristiansund municipality's ER organization was crucial for the handling on land. Public and private health resources, consisting of professionally responsible physician, corporate physician, emergency physician and the municipality's infectious disease control physician, were involved in the infection control and health work. Moreover, Equinor, the Norwegian state-owned company responsible for helicopters used for medical evacuation, and Avinor, responsible for air traffic management, were involved in the response operation. On August 5th, Neptune Energy chose to transit from a traditional emergency organization to a nominal one. The rig was declared free of infection on August 13th.

4.2.2. 2nd line involvement

We reconstructed the 2nd line involvement starting from the CIM reports. On August 1st ERM was notified of patient #1 tested positive on Covid-19 in the evening (20.00). ERM made contact with the professionally responsible physician (FAL, Faglig Ansvarlig Lege, in Norwegian language) who mobilized his own team at the rig operator. ERM also notified the 3rd line Emergency Manager about the incident. At 20.23 ERM decided to handle the case as an emergency situation, mobilizing the ERT. He called the COS to obtain information, plan for further handling in cooperation with FAL and 3rd line and manage media sources. Logistics Coordinator of the ERT alerted Neptune logistics base in Florø and obtained that WP would have sent a list of everyone who was on board the helicopter to and from WP on 29th of July and on 31st of July. A total of 27 passengers and four pilots were alerted. Table 1 summarized the main events per each day.

4.2.3. FRAM model of the 1st case

The first case was handled by OFFB as any other case of emergency: all the ERT was alerted and participated in the management of the situation. In this 1st case, 2nd line activities can be divided into the four operational phases described in section 3. As introduced in the method section (cf. section 3.4), we utilized a four-layer FRAM [48], where each layer is connected to other time layers via functions that belong to multiple layers, or via functions in a layer whose *output* constitutes one of the *inputs* (I, C, R, P) in another layer. For consistency, this model and the others in the following paragraphs are discussed using specific tags for functions and aspects as follows: < Name of Function >, 'name of aspect'.

For the presentation of our FRAM models, we used colours to code the actors involved in the ER operation:

- ERM: Purple;
- COS: Green;
- LC: Blue;
- AC: Yellow;
- PC: Grey;
- IC: Red.

4.2.3.1. *The first phase: mobilization.* The mobilization phase starts when ERM < Receive the first notice > with the precondition that their duty mobile phone is available. Therefore, ERM < Assess potential needs and actions > and < Notify the COS > about the situation, by filling-in the Quick Card. ERM < Establish the event in CIM > allowing the whole ERT to share information and to have a common operating picture. The COS < Clarify immediate actions related to potential and resource needs > and the result (Output) of this function 'Notification to ERT' is used to give notice ERT's four agents and < Mobilize the ER team >. The ERT agents perform their usual tasks for

Table 1
Synthesis of daily main events for Case 1.

Day	Relevant Events
August 1st	At 22.15 the Drilling Manager at WP called ERM, after several attempts made by ERM to establish a contact. The Supervisory Coordinator of the ERT contacted the PSA of Norway and fixed a status meeting for the next day at 12:00.
August 2nd	On August, 2nd there was a meeting between 2nd line and FAL's staff at Seadrill (the rig owner). After the status meeting with the PSA, it was clarified that no notification form was required, as it was disease-related incident. At 19.30 ERM demobilized the 2nd line ERT and handled the incident himself.
August 3rd	On August, 3rd ERM, FAL and the infectious disease doctor in Kristiansund had a coordinating meeting by phone. In the afternoon ERM had several phone calls with the Emergency Manager in Kristiansund municipality about reception of Covid-19-positive patients, exchange of information on follow-up procedures, confirmation of reception of patients, etc.
August 4th	On August, 4th the Drilling Manager informed ERM that he was quarantined in the cabin, further follow-up of Drilling superintendent on land. Patient #2 was sent to isolation facilities in Kristiansund.
August 5th	On August, 5th during a status meeting with Neptune normalization project was established. Fifteen people were received in Kristiansund, OSEP ^a and municipal reception involved up to fifty personnel from quarantine or isolation at WP. A status meeting was organized internally in OFFB to coordinate resources in the event. Patient #3 was sent to isolation facilities in Kristiansund.
August 13th	On August, 13th ERM called the PSA to consider the situation normalised.

^a SAR helicopter, Evacuation centre (OSEP) is a location for physically uninjured persons who have been involved in an incident, etc.

an emergency situation: i.e., the Authority Coordinator < *Notify the PSA* > while Logistics Coordinator < *Mobilize SAR helicopter* > and < *Contact the logistic provider* >. This phase ends when the coordination between ERM and 3rd line is complete and the ERT agents mobilize their stakeholders and < *Update info in CIM* >. In this regard, the functions related to CIM constitute the connection with the other time-layers.

4.2.3.2. The second phase: alert. In the alert phase, ERT coordinators notify all the relevant stakeholders about the incident. For instance, COS < *Establish contact with the 1st line* >, IC < *Contact operators media/communication* >, LC < *Consult with JRCC² about resource allocation* >, PC < *Notify the oncall physician* >. In this case, unlike the standard ER procedure, ERM decided not to notify the police, NOFO,³ the Norwegian Coastal Administration, as this was a health-related incident. Once these actions are performed and CIM is updated by each coordinator, < *ERM: Conduct 1st meeting for Situational Assessment (SA)* >, where the whole ERT identify possible remedial actions and support measures, as well as plan the next operations.

4.2.3.3. The third phase: combat. The combat phase is related to the ER handling. In this phase, resources are provided according to the action plan, which is the Output of joining the 1st meeting for situational awareness (second phase). The action plan includes carrying out research of health personnel, procurement of infection control equipment, evacuation, and personnel care to deal with the event. Some of the combat-related actions, typical of 2nd line ER management and conducted by ERT agents are: LC < *Mobilize helicopters following action plan (1st meeting)* > and < *Inform relevant helicopter company about changing scheduled trips* >; PC < *Establish contact & coordinate actions with HR 3rd line (operators & owner)* > and < *Send the POB list to the relevant stakeholders* >; CIM < *Update the PSA about the sit. Regularly* >; IC < *Keep the 3rd line up to date with status, updates every 30 min* >. During combat phase the role of COS is to ensure that the whole ERT has an updated and common operating picture. In this regard, the technological agent, CIM, has a critical role in ER operation and performs a crucial task: < *CIM: Provide information* > to each coordinator.

In the Covid-19 case management, on one hand some actions like updating police or NOFO, submitting oil pollution action plan, or controlling the submission of the warning form for gas emissions are not performed, because this is a health-related incident. On the other hand, some specific actions are performed in addition to those of the standard procedure. For example, ERM < *Assess the need for evacuate new patients* > and shows the 'identified actions for evacuation' during the situation meeting with the ERT and AC < *Update Kristiansund municipality* > regularly and < *Apply for temporary quarantine areas (if needed)* >. Moreover, ERM < *Coordinate support with Neptune Energy* > obtaining 'a brand-new PCR test machine' and 'specialized operators' to test people offshore and < *Coordinate admin. needs with Kristiansund municipality* > in terms of 'reception of Covid-19 positive patients or info on follow-up procedures'.

All the performed actions are registered in the CIM by the agents, giving a continuity over each layer. When 1st, 2nd and 3rd line ER authorities agree that the emergency is over, this phase ends for the 2nd line.

4.2.3.4. The fourth phase: normalization. The last phase sees a transition from responding to the event to bounce back to a normal situation. Some actions performed by ERM, like < *Verify with 1st line that situation is under control* >, < *Verify with 3rd line any support needed from 2nd line* >, and < *Ensure PSA approval for a transition to normalization* >, are aimed at finding a consent between all the ER authorities about the transition to normalization phase. Once there is a mutual agreement, ERM < *Organize and conduct debriefing ERT* >. For the 2nd line ERT, this phase means also debriefing, sharing experience, and assessing the response activities according to best practices. To model this situation, a collective function at organizational level, named < *ER Team: debriefing meeting* >, has been introduced. The Output from this function provides 'Lessons from ER operation'. These lessons will enhance the handling of next emergencies, by identifying and implementing the best practices, through a continuous organizational learning cycle. Fig. 4, proposing a visual understanding of functions related only to the Combat phase, confirms the tightly coupled nature of the process at hand. As we introduced in par. 3.5, in the FRAM model each function can be described through six fundamental aspects: Input (I), Precondition (P), Resource (R), Output (O), Control (C), Time (T), graphically represented at the corner of a hexagon.

² Joint Rescue Coordination Centre (JRCC) is the 3rd line ER organization (operators).

³ The Norwegian Clean Seas Association for operating companies.

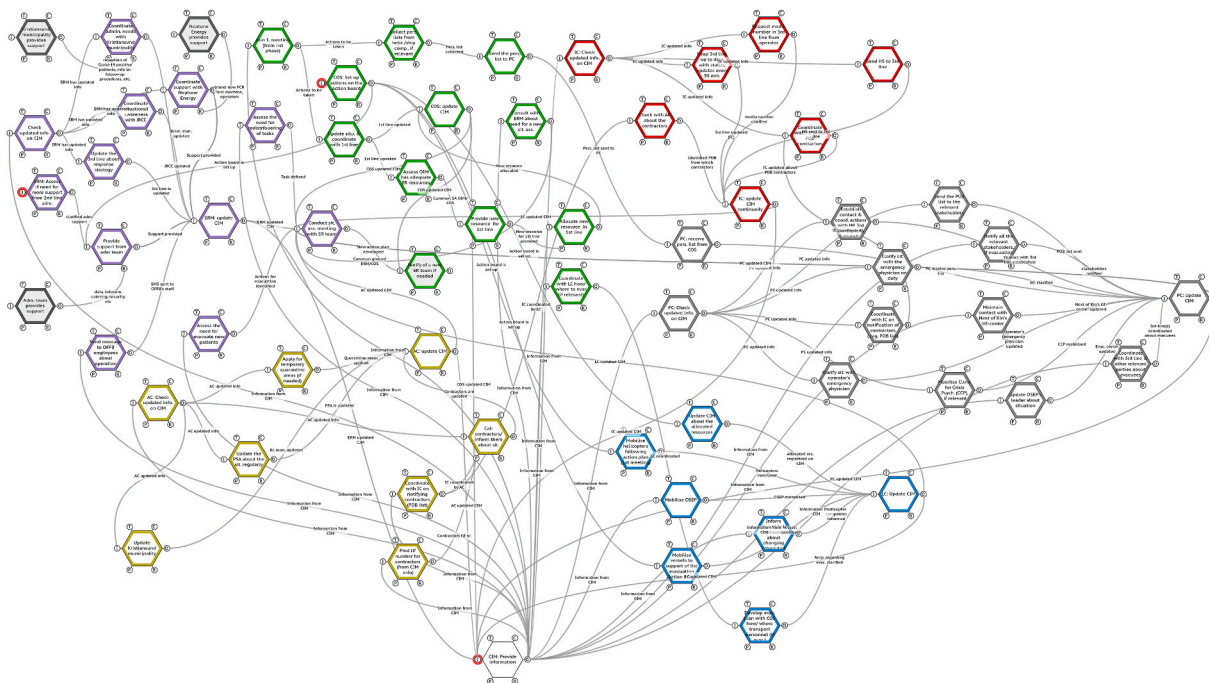


Fig. 4. FRAM model of the 1st case – combat phase.

4.3. Case 2

From Monday 19th to Thursday 22nd of October, another Covid-19 related emergency was reported at WP rig.

4.3.1. Event summary

A person with potential Covid-19 symptoms was transported to the city of Kristiansund on Friday 16th and was confirmed infected the following Monday. FAL, Florø logistics and Kristiansund municipality were coordinated by OFFB. Later, fifteen possible close contacts who had left the rig were notified at home to be tested and quarantined; contemporarily several people with symptoms were isolated offshore (8 close contacts). Two days later, on Wednesday, two new cases were confirmed, and new close contacts were isolated on board. A total of three people were confirmed infected by Covid-19 and isolated; sixteen people were quarantined in a hotel in Kristiansund or at their home, and two more people on the rig. Other personnel were transported to the rig on Thursday and Friday to replace those sent shoreside, either isolated or quarantined. The event was considered concluded on Friday 23rd of October (seven days later) when the rig was declared safe once more.

4.3.2. 2nd line involvement

ERM was notified by the Neptune Covid-19 project on Monday afternoon (19:10). Neptune emphasized that it was not an emergency situation and communicated that Seadrill (the rig owner) had to be in lead. From the 2nd line, Neptune requested support for the direct notification of the fifteen possible infected people who had returned home. ERM received the list of their names, but telephone numbers were not available on that list. Therefore, ERM asked Florø Air transport office the telephone numbers of the involved people and together with COS started calling the listed personnel. On Tuesday, ERM was asked to draft a PSA form; it was approved by 3rd line and submitted by ERM 2nd line. A total of three updates were sent to the PSA. When it was confirmed that another two people were infected, Neptune strengthened its project group and involved ERM 2nd line as part of the group, whereas traditional 3rd line was not mobilized. ERM had daily contact with Drilling Supervisor⁴ (DSV) on the WP, regarding general status on board and progress in the operation.

At the same time Neptune expanded its project group, ERM established a new session in CIM, without mobilizing the emergency room. From Wednesday, joint status meetings were set up on Teams between the Neptune project (including ERM/COS 2nd line), Seadrill and other involved actors. 2nd line took the responsibility of updating the situation on board in CIM after joining status meetings.

In summary, 2nd line involvement resulted in a hundred of phone calls for ERM or COS. ERM decided to not mobilize further resources in the ERT but coordinators in the 2nd line (rest of the 2nd line ERT) were continuously updated via SMS by COS.

⁴ The Drilling Supervisor is the engineer responsible of the drilling operation on board the drilling rig offshore.

4.3.3. FRAM model of the 2nd case

In this second case, 2nd line involvement was less demanding than the first case (cf. Section 4.2.2), since only ERM and COS were actually managing the situation. The FRAM model reflects this observation (see Fig. 5), as visible when compressing the analysis to one single layer (rather than 4 as for Case 1).

The process starts when < ERM is notified by Neptune > with precondition < To have duty mobile available >. Then ERM < Fill-in the Quick Card > and < Notify the COS >. ERM < Ask telephone numbers to Floro Logistics > and after 'phone numbers from Floro Logistics' were available, ERM < Contact involved personnel > and < Contact contractors > to notify the situation. Same actions are done by COS. Situation awareness is fundamental at this stage. Therefore, ERM < Contact WP DSV daily >, to have the situation updated and < Join status meeting with Neptune, Seadrill and others > together with COS regularly, in order to monitor the evolution of events. To share information, ERM < Establish the event in CIM > and takes care to update the tool every time a new event occurs. ERM < Notify PSA > after 'PSA form was approved' by 3rd line, while COS < Update 2nd line ERT via SMS >.

4.4. Case 3

A third Covid-19 infection case happened at West Mira (WM) rig, operating for Wintershall Dea, from Thursday December 31, 2020 to Saturday January 2, 2021.

4.4.1. Event summary

After a flight of the previous day with nineteen people from Flesland to WM, one of the passengers was tested positive on Covid-19 on Thursday December 31, 2020. The patient was transported to shore by medical evacuation helicopter; twenty close contacts were transported to Bergen - Flesland airport the following day by helicopter from Flesland. These people had to be quarantined at a hotel in Bergen or had to travel home for the quarantine (one infected by Covid-19 and twenty people defined as close contacts).

ERM tried to get in touch with the emergency hotel Scandic Kokstad without success, because it was closed for the Christmas period. Afterwards, ERM managed to book some rooms at another hotel, where the people were transferred and tested with the help of a nurse delivered by the Offshore Health Services⁵ (OHS) company.

4.4.2. 2nd line involvement

On Thursday afternoon (17:23), ERM received a call from the Drilling Superintendent⁶ on shore of the Wintershall Dea⁷ company and afterwards contacted DSV at WM, regarding the situation offshore, and called 3rd line and COS. ERM learned from the Duty Doctor⁸ that the result of triage of the patient was green and gave this information to DSV in order to fill the PSA form. ERM alerted the PSA duty manager about the incident at WM and gave an update on the situation at WM to the Authorities. The following day a Teams meeting was organized with ERM, Wintershall Dea (operator), Seadrill (rig owner) and WM (rig). After some troubles due to the identification of the Covid hotel open during Christmas holidays, ERM obtained the direct number of the Scandic Flesland hotel from the emergency Medical Service Centre in the city of Bergen and booked 15 rooms. ERM called the Managing Director of the OHS company to organize a support scheme for those who were in quarantine. In this case, OHS delivered a nurse to follow up the personnel situated in quarantine at the Scandic Flesland hotel. ERM called the nurse from Seadrill who had accompanied the passengers from the heliport to the hotel; 15 people were on the first flight. 3rd line Manager on duty called for an update and agreed to test those in quarantine at the hotel, if possible. Coordination meeting with nurse from Seadrill was organized. All twenty-one people were transported to land and through the hotel; six people were left in the hotel. At the end, ERM called and demobilized resources from the OHS company, that is the psychiatric nurse.

4.4.3. FRAM model of the 3rd case

Even for the third case, 2nd line involvement was not as complex as 1st case (cf. 4.2.2) and the situation was handled by ERM and COS without activating the whole 2nd line ERT (Fig. 6).

At first, with the precondition that ERM's duty mobile was available, < ERM is notified by Wintershall Dea > because 'logistic assistance is needed'. As consequence, after notifying COS, ERM < Call Logistic Duty > to have a 'helicopter flight planned' and < Contact Medical Service Centre >, asking for 'hotel details' where to send people for quarantine. After finding out which hotel was open during Christmas holidays and having a flight scheduled, ERM < Contact hotel for quarantine > and < Book 15 rooms >. To obtain 'medical info', ERM < Contact FAL > and, to have an updated situation awareness, he < Contact DSV at West Mira > and < Join status meeting with Wintershall DEA, Seadrill and others > together with COS. As in the other cases, ERM < Establish the event in CIM >, keeping the tool updated to < Provide information > to other members, and < Notify PSA > after having the 'PSA form approved' by 3rd line. Finally, ERM < Call Duty Doctor Company > to have 'a nurse delivered' at quarantine hotel, who will assist and test the isolated people.

⁵ This company delivers the Duty Doctor services and other medical support services to the O&G companies.

⁶ The Drilling Superintendent is the person who has the overall responsibility of the drilling operation (drilling engineer). She or he is stationed onshore and is superior of the Drilling Supervisor on board the offshore rig, when it comes to the drilling operation.

⁷ Both Wintershall Dea and Neptune Energy are O&G companies, operating on the Norwegian continental shelf.

⁸ There are two doctors involved: One is the onshore 24/7 Duty Doctor and the other is the onshore doctor responsible of the health services on board the rig (FAL). Normally, the nurse on the rig will call the 24/7 Duty Doctor for consulting an ill patient. The FAL has the overall responsibility of contagious disease outbreaks on board, and will decide/advise how to handle the situation.

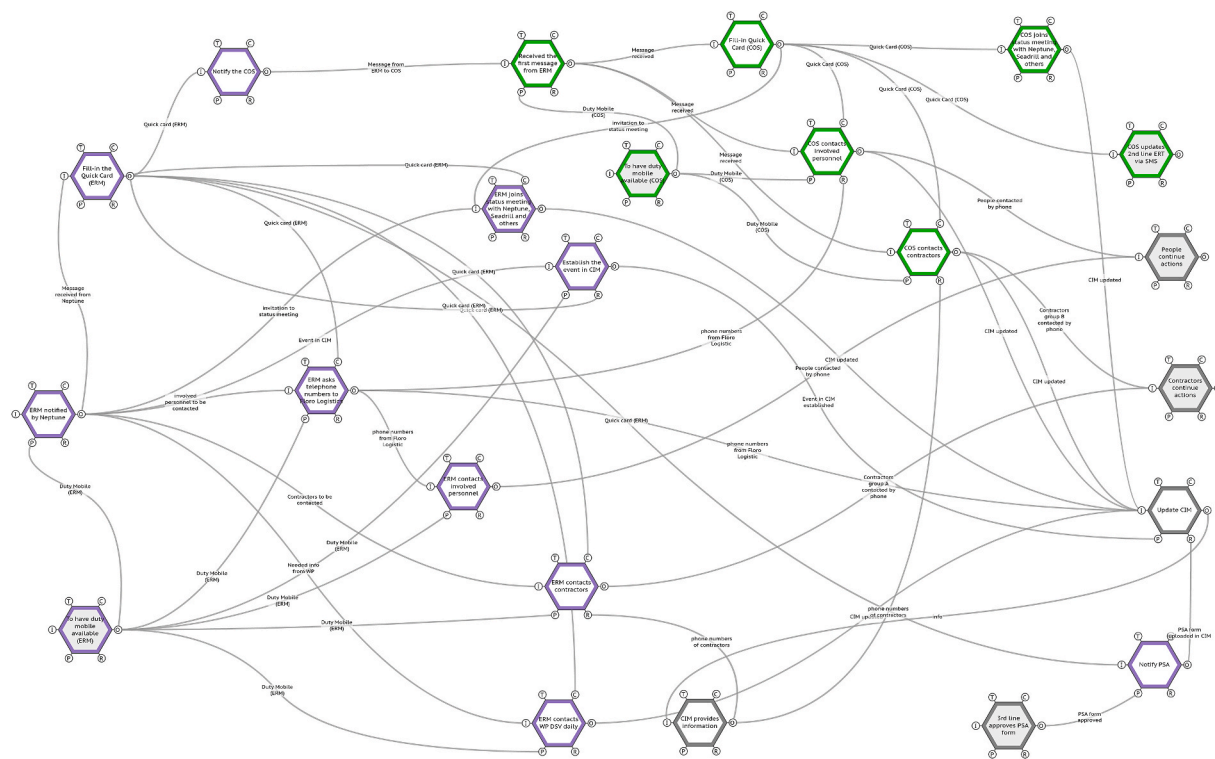


Fig. 5. FRAM model of the 2nd case.

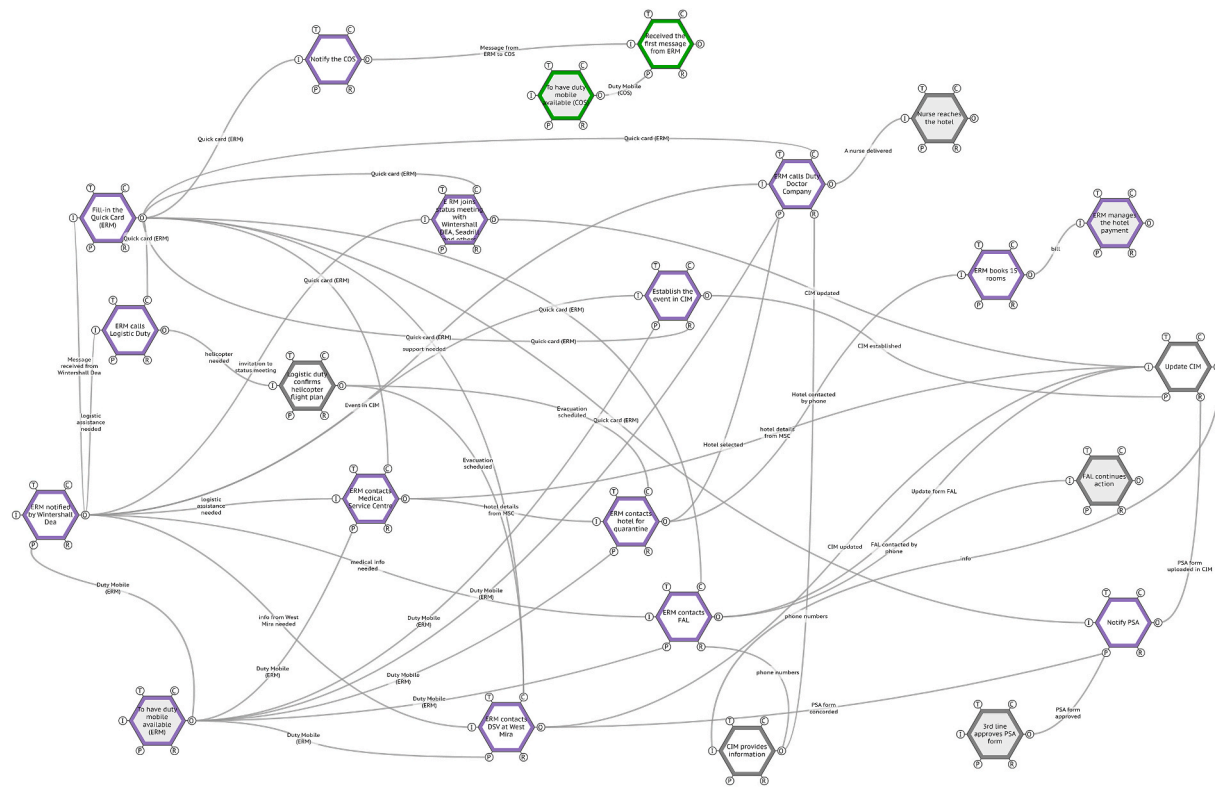


Fig. 6. FRAM model of the 3rd case.

5. Discussion

From an empirical point of view, our study on organizational resilience and dynamic adaptive behaviors of an EM company was entirely built on FRAM. This method was firstly utilized for elaborating a WAI model based on the available OFFB's documents and afterwards to develop the WAD models of the three episodes, which allowed to understand the reconcile organizational planning and adaptive capacities.

The three Covid-19 events at WP have been handled by ER organizations at different levels and involved a number of actors, who required close cooperation, good coordination and clear communication. The formalization of such interactions between agents through the FRAM offered a methodological solution to consistently investigate each event, maintaining coherence and facilitating a systematic crisis-induced learning.

The FRAM models demonstrate a smoother EMS put in place by OFFB following the very first case, both at the level of the actors involved and about the number of activated functions or interconnections between them (see Table 2).

The elaborated FRAM models are the result of a structured learning effort, collecting data from different sources into a harmonious representation. The outcomes of the models, and even the process to define them, emphasize the tight relationships among a plethora of agents and respective activities involved in mission command.

While each emergency will always be ultimately different, the three cases were considered a reasonable basis to explore examples of crisis-induced learning in relation to Covid-19 infections. Considering the qualitative nature of our approach, an inductive thematic saturation was achieved during the focus groups [56]: following the third case, new Covid-19 infection cases were considered standardized incidents, without major unexpected emerging behaviours to be expected. Accordingly, a model of the procedure to manage Covid-19 offshore infections has been developed to describe the migration of take-ways from crises-induced learning into organizational planning.

5.1. Learning from case 1

In this event, the 2nd line ERM activated all the ERT as in any other emergency case. Since it was all about a novel incident type, the situation suffered from great uncertainty. According to a 2nd second line informant, uncertainty was related to several aspects: how many people could be infected on board the rig; whether the infection could be limited; whether the infection tracking, carried out from land, was sufficient; how the situation should be managed in terms of privacy; how tests should be done safely; what equipment would be used for testing on the rig; how tests should be transported to shore for analysis; how close contacts should be handled and looked after on the rig and who was responsible for decisions related to new material and personnel sent out to the rig.

Moreover, our informants point out that the planning system gave those involved a good overview of formal routines roles, responsibilities and distribution of tasks for actions and interactions. At the same time, plans did not provide clear guidelines about who was responsible for notifying the responsible for air traffic management and the helicopter company of Covid-19 cases or suspected ones. There was no clear guideline for mapping close contacts among fellow passengers and crew, testing of personnel offshore and how to proceed to test the entire crew of the rig. This climate of uncertainty and the lack of specific procedures for this new kind of emergency made decision-making an even more difficult and demanding task. As expected from literature, this situation describes an incomplete organizational planning, mainly due to the novelty of the situation.

One of the critical decisions was related to the extent of contagion: since the municipality did not have sufficient capacity to carry out the tests, the operator took responsibility for setting up a separate test centre to assess the contagion situation at WP.

The operator had created plans and procedures for handling Covid-19 before the situation occurred, but they could not describe all eventualities. Therefore, the crisis management had to improvise and solve larger and smaller challenges as they emerged, without necessarily having prior approval and signature on the decisions made. In this case, examples of improvisation can be identified in the use of a brand new PCR test machine and in the operator that set up a separate test centre. The result of these two specific decisions was satisfactory since they carried out without burdening the public capacity and contributed to the streamlining of the testing process.

Despite important progress towards adaptability in contingency planning, this Covid-19 case shows that there was still a need for much more adaptive planning so that ever-changing operational conditions can be met in less predictable circumstances. However,

Table 2
Summary table of the three FRAM models.

Description	Case 1 (combat phase)	Case 2	Case 3
AGENTS			
ERM	13 functions	11 functions	15 functions
COS	12 functions	7 functions	2 functions
LC	7 functions	–	–
AC	8 functions	–	–
PC	13 functions	–	–
IC	7 functions	–	–
Others:	Kristiansund municipality (1 function); Neptune Energy (1 function); adm.team (1 function); CIM tool (1 function).	3rd line (1 function); contractors (1 function); involved personnel (1 function); CIM tool (2 functions).	3rd line (1 function); Logistic duty (1 function); FAL (1 function); nurse (1 function); CIM tool (2 functions).
Total number of functions	64	23	23
Total number of couplings	112	43	45

adaptation is not about always changing plans, models or past approaches, but ensuring authority, capability and potential to revise and modify them [2].

5.2. Learning from case 2

As it appears evident from the FRAM modelling, this Covid-19 incident significantly differs from the previous one. In this occasion, the handling started as a project in Neptune Energy and there was no mobilization of the “traditional” emergency response organization during the incident. Neptune wanted Seadrill (the rig owner) to coordinate the handling, unlike the previous case where Seadrill held a marginal role.

Initially, Neptune Energy decided not to involve the emergency response organization, handling the situation in an established project: therefore 2nd line was not involved in the very first hours of the incident. Then, the project group asked the 2nd line to notify the contractors, causing some confusion in the 2nd line organization because, despite the project group did not want to define the situation as an emergency, they actually called the 2nd line for support.

Neptune expectations for the 2nd line role in the incident were unclear in the first stages. OFFB requested a coordination meeting with the Neptune project group to clarify the composition of the project group and expectations for the 2nd line. The meeting resulted in a better understanding for both parties.

In summary, the second case points out an initial uncertainty from the operator about the roles and the task of the various actors and a lack of organization about the handling of notifications to the involved people. Such observations offer recommendations to further improve the process and ensure a smoother organizational planning.

5.3. Learning from case 3

This third case highlights additional critical aspects. Firstly, ERM did not receive any information/help from FAL about transportation and hotels where send the quarantined people. ERM also called the operational support centre “Equinor marine”, asking for information about quarantine hotel that Equinor⁹ normally uses, but there was no result. Finally, ERM was notified by Bergen municipality that Scandic Flesland was the hotel used in this occasion, whereas the regular Covid-19 quarantine hotel at Scandic Kokstad was closed for Christmas holidays.

Another issue regarded the failed attempt by ERM to obtain “infection control” taxi, that is to request a taxi allowed to transport personnel going into Covid-19 quarantine. The Bergen Municipality did not give OFFB the right procedure to organize this type of transport and ERM had to find out themselves.

Besides these specific issues, the situation was handled very skillfully and solved over a weekend.

5.4. Trading-off organizational resilience and planning

The successful handling of three different Covid-19 cases was translated in double-loop learning [42], and learning opportunities were collected into an organizational procedure by OFFB [53]. This document allows moving from the management of individual specific cases towards a basic management plan, to be interpreted as a guide for handling of Covid-19-related incidents offshore. Acknowledging the inherent variability of such emergency situations, procedure stays at a relatively abstract level, to ensure the possibility of adapting the plan on a case-by-case basis, giving the right space to improvisation [17]. The document trades-off the need for variability in certain operations with the identification of common hotspots coming from learning, and shared discussions after the three previous cases.

5.4.1. A newly introduced Covid-19 procedure for EM

In line with the research question of this paper and for brevity, we present only the Operator’s 2nd line responsibilities and tasks for the combat phase, formalizing them through a dedicated FRAM model. The Operator’s 2nd line is expected to be responsible for coordinating operational activities from onshore – to requisition relevant resources and coordinate actions, as per the following tasks:

- to communicate and coordinate activities with: 1st line; 3rd line; the Duty Doctor; the Company Doctor responsible for the rig; the Logistics Department; the helicopter operator (if the Logistics Dept. is not addressing this); relevant personnel employed by the Operator, such as the company doctor or staff responsible for health- or working environment-related matters; the Rig Owner (if the rig is leased); contractors (if the rig is leased, and in consultation with the Rig Owner); the operator providing transport from the helicopter to the hotel; the quarantine hotel; contracted health personnel; area emergency response organization; the Norwegian Joint Rescue Coordination Centre;
- to report and provide status updates to the PSA (carried out in coordination with 1st and 3rd lines);
- to manage the practical reception of personnel at the helicopter base, bus transport, and the reception of personnel at their quarantine/isolation hotel(s). Accordingly, 2nd line operator shall coordinate with the Company Doctor responsible for the rig, 3rd line, the helicopter operator, the transport operator, the hotel(s), on-site representative(s) and the municipality;
- to determine, in consultation with the Company Doctor responsible for the rig, whether people in categories C and D need to be accompanied during helicopter transport. They shall make sure that companion personnel are obtained, as appropriate. This shall be coordinated with 1st line, the Logistics Dept., and the helicopter operator;

⁹ Equinor Marine is an 24/7 operational surveillance and logistics centre. Equinor is the largest operating oil & gas company in Norway. They provide surveillance services to other companies.

- to ensure that either the Logistics Dept. or 2nd line itself communicates and coordinates with the helicopter operator to make sure that infection control measures are implemented on arrival at the helicopter base;
- to ensure that the Operator/Rig Owner assigns personnel who can meet and take care of persons who are transported onshore;
- to ensure that personnel, who arrive onshore, receive the necessary information and supervision.
- to ensure that the quarantine hotel receives the information it requires;
- to ensure that infection control measures are implemented in cases where personnel require a hired car to drive to the quarantine location;
- to keep 1st line, 3rd line, the Company Doctor responsible for the rig and the municipality updated on the status of personnel who are sent onshore, and shall deal with any questions that may arise.
- to ensure that essential infection control equipment is obtained, as appropriate;
- to check with the Company Doctor responsible for the rig and the municipality to determine if there is any need for support from the Operator to carry out testing onshore. If necessary, he/she shall make sure that the municipality receives the support it requires for testing.

5.5. FRAM model of procedure for Covid-19 infection management

Fig. 7 depicts the core phase of the procedure, i.e. combat, in FRAM terms. At first, < offshore nurse visits patients > and < Duty Doctor does the triage>, sharing the ‘triage results’ with Company Doctor. < Duty Doctor updates the status of personnel offshore > with 1st line and 2nd line ERM and has ‘to notify this information to 3rd line within 15 min’. With the precondition that < Communication equipment functions regularly>, ERM < Communicate and coordinate > with all the actors we mentioned in the previous paragraph.

Those communication and coordination functions are essential to guarantee the execution of other relevant actions by ERM. For example, ERM < Report and update to PSA > in coordination with 1st line and 3rd line, according to ‘Norwegian Law’, which constitutes a control for this action. Moreover, ERM < Manages the reception at helicopter base>, after communicating and coordinating with 3rd line, Company Doctor, Duty doctor and helicopter operator. Precondition for this action is that ERM < Implements ASAP infection control measures > and Resources are ‘assigned and trained personnel to handle the situation’. Same couple of Precondition/Resource can be found for the actions ERM < Manage the transport by bus/hired car>, ERM < Manage the reception at the hotel>, and ERM < Manage the transport by helicopter>. For this last action, another input is also necessary: ERM < Determine the accompaniment>, under control of Duty Doctor, and in coordination with 1st line, Logistics Department, and helicopter operator, having as resource the

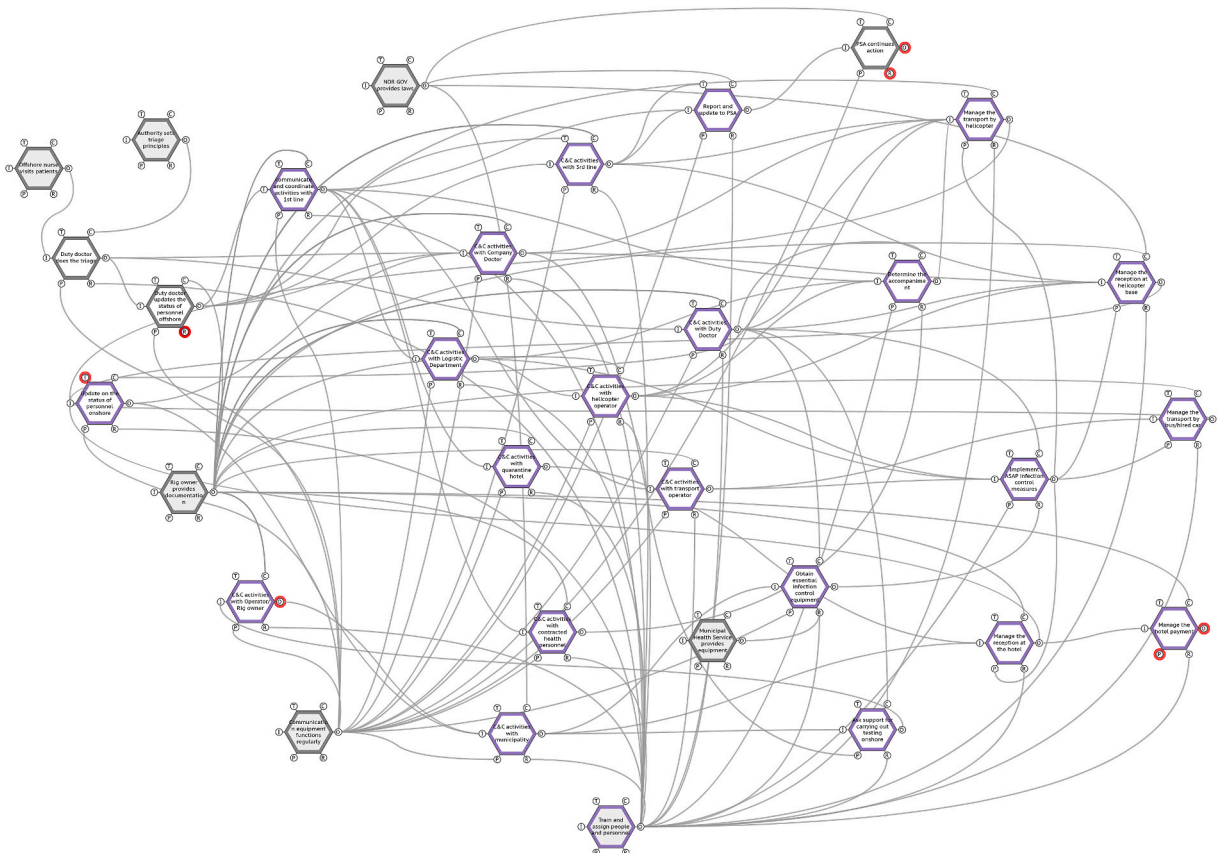


Fig. 7. FRAM model of procedure - combat phase.

accompanying people from contracted health personnel. ERM < *Obtain essential infection control equipment* > from Municipal Health Service, under the control of Duty Doctor, and in coordination with the municipality; the output of this action is fundamental for implementing ASAP infection control measure, as we saw before. Another action, related to medical needs, is ERM's < *Ask support for carrying out testing onshore* > to rig operator in coordination with municipality and the consultation with Company Doctor as precondition, under the control of Duty Doctor.

Most of the actions of the FRAM model share, as Control, the content of some documents that should be provided by the rig owner: the three plans ('Covid-19 plan', 'infection control plan' and 'communication plan'), the 'Emergency response bridging document' and the several 'contracts' stipulated by the operating company with: the health personnel, the helicopter company, the transport company, and the quarantine hotel.

Closing the loop, actions such as ERM < *Manage* > have as Output 'updated info': the latter constitutes the input for the action ERM < *Update on the status of the personnel onshore* > towards the Company Doctor and the municipality, in coordination with the Duty doctor.

The analysis of this procedure recalls the founding principles of "mission command", i.e. decentralisation and empowerment of subordinates [57]. This reasoning became pervasive also in other operational contexts, such as clinical theatres during Covid-19 emergencies, where great responsibility is pushed down to the level where operators can best employ it [58].

6. Conclusion

Within the wide literature on organizational resilience, this study allowed defining different learning opportunities from a novel type of emergency, i.e. the management of Covid-19 infection cases offshore. The empirical study of the organizational resilience, based on three Covid-19 related cases in oil platforms offshore, pointed out the evolution of an ER organization, along with its capacity to adapt to new challenges and to learn from previous episodes.

The first case was managed through a traditional ER approach revealing uncertainty and lack of specific procedures, with risks to be managed and situations to be faced highly different from the planned ones. Despite this unanticipated complexity, the whole EMS proved to be resilient, being capable of resolving situations that were not included in original emergency plans, via improvisation. The following cases were handled with less involvement of the 2nd line ERT and more participation of the 1st and 3rd line operators, following the crisis-induced learning. But difficult case management cannot be delegated only to improvisation: the 2nd line operators enriched its capacity to provide support to both the 1st line and the 3rd line ER organizations through a novel procedure which indicates functional hotspots valid for a wide variety of Covid-19 cases. The case studies confirm that EM organizations benefits from an efficient and transparent reporting system to foster continuous learning from events and consequently enrich decision-making at strategic level. The results adheres to RE traditional expectations [59], highlighting the need for a unity of effort, implemented through centralized planning and decentralized execution to empower mutual understanding and rapid decision-making [60].

It is important to observe how the whole analysis was conducted using the FRAM, a systemic approach currently applied in EMS only to a limited extent. Nonetheless, the study confirms FRAM role to support a structured learning for organizational resilience and planning. The use of FRAM made it possible to identify which actors were involved, to define the various functions and to identify the interconnections between them, for both actual practices and prescribed work. These empirical findings document the benefits arising when studying multiple varieties of socio-technical work. This research is fully aligned with recent RE contextual information and need of integrated investigations on the nuances of adaptation [61] for Work-As-Observed (WAO), Work-as-Prescribed (WAP), Work-as-Normative (WAN), Work-As-Disclosed (WADI) [62]. When looking at an incident, knowledge on each of these varieties, their small disturbances, their inconsistencies, ambiguities, conflicting goals is needed to further extent crisis-induced learning [62]. On this path, this research demonstrated the applicability of FRAM to study the responses a socio-technical system puts - or may put - in place to unforeseen emergency situations: FRAM helps gathering knowledge and organizing it systematically.

Additionally, the study allowed extracting virtuous characteristics of an organization that can be extended to other scenarios, helping to define best practices for a safe and efficient crisis management. This last aspect promotes a positive learning attitude to openness, beliefs and perceptions sharing, and mutual trust to inform decision-making at different organizational levels. All these aspects are recognized to be central for ensuring success in spite of disasters, and should guide decision-makers to ensure organizational resilience [63].

While FRAM exceeds traditional accident analysis and risk management models, which are usually subjected to limitations imposed by linearism and reductionism (e.g. domino models, fault tree analysis, event tree analysis, etc.), it is not yet a complete approach to deal with any situation [47]. For future research, the FRAM could be utilized for analysing procedures and activities of more complex emergency or crisis management organizations, both civilian and military. Next studies could extend the findings of the proposed FRAM models, recurring to quantification approaches, such as Bayesian networks or fuzzy sets, or simulations. FRAM-like methods are expected to support investigations of WAX varieties, increasing the proactive nature of crisis management and crisis-induced learning for diverse operational settings [62].

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.

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