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The chimera of time: Exploring the functional properties of an emergency response room in action

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Abstract

Emergency response (ER) planners have developed plans either under "all-hazards" approach, focusing on a full spectrum of emergencies or under a specific scenario—in which planning underlines aligned actions to respond to a particular situation. Either of them represents the so-called Work-As-Imagined (WAI) operation. However, the growing complexity, the scope of emerging situation and the level of uncertainty, create unpredicted challenges for ER operation, which represent another variety of work named Work-As-Done (WAD). These challenges require different degrees of adaptation to avoid the cascading impacts of an event into an accident, or even a disaster. Drawing upon the traditional Functional Resonance Analysis (FRAM), we provide a novel FRAM representation, which reflects adaptive capacities on functional inter-relationships, and their evolution over time in different scenarios. Rather than using time as an aspect of the FRAM hexagon in its traditional sense, we propose an explicit time-dependent analysis. We outline how to make the chimera of time response feasible in ER operations and how to represent respective sources of success. Based on our FRAM approach, we conduct an incident analysis referred to an event that happened in Gjøa in 2017, in Norway at the North Sea, to understand adaptation in the four different ER phases, that is mobilizing, alert/warning, combat and normalization.

KEYWORDS

complexity, emergency response, Functional Resonance Analysis (FRAM), socio-technical systems, uncertainty

1 | INTRODUCTION

A number of major accidents in the energy sector have increased global awareness of emergencies in terms of both injuries and fatalities, ecosystem damages and financial costs (AlKazimi & Grantham, 2015). Previous experience has shown how such accidents may originate either from natural hazards or human-made actions, or tight combinations of them (Cabrera Aguilera et al., 2016; Necci et al., 2019). The extension and effects of an emergency depend on the capacity of the Emergency Management System (EMS) to reduce the system's vulnerability. It also depends on a harmonic orchestration of human, technical and organizational components despite the complexity experienced during a contingency. This orchestration shapes by the extent of being prepared for, respond to, and recover from both expected and unexpected events. In other words, it depends on *the resilience of the EMS* (Tveiten et al., 2012).

Resilience, and its engineering in an EMS system, offers approaches to ensure adaptive capacity to sustain changes and dealing with uncertainties (Patriarca et al., 2020). A resilience-based EMS is here proposed as a system able to anticipate and increase preparedness and adequately respond to critical changes during an emergency response (ER) operation.

An EMS includes four interwoven stages: preparedness, response, recovery and mitigation (McLoughlin, 1985). These stages are usually operated in three hierarchical levels, including the operational (1st line), tactical (2nd line) and strategic level (3rd line). Whereas the first-line response activities are performed by those closest to the scene (e.g. on a platform installation or rig), and third-line acts as the organization's strategic unit, the second-line emergency response provides operational and tactical support to both first and third line. These activities are largely prescribed by international and national standards (e.g. ISO 22320, 2018), handbooks, organizational procedures and prescriptive work descriptions which constitute an imagined variety of the work domain, that is Work-As-Imagined (WAI). On the other hand, the challenges operators have to deal with, when an event happens, require different degrees of adaptation to avoid the degeneration of that event into an accident, or even a disaster. This observation implies that the real actions are inescapably different from the WAI, constituting another variety of work named Work-As-Done (WAD).

Even though such distinction applies at all level of emergency response, the focus of this research is primarily on the initial response phase: the immediate aftermath of an event/incident, as performed at the tactical level, that is the 2nd line. This response phase includes a large set of activities to be conducted (e.g. the gathering of information, the anticipation of possible cascading events and response coordination), with precise time sequence to ensure ERM success.

During an ER operation, timing remains the most critical tactical aspect that affects the effectiveness of any operation's success. Time constraints are crucial when receiving emergency warning messages (D'Arienzo et al., 2020), evacuating affected people, coordinating available resources and deciding on priorities, or deciding which information is relevant to share with appropriate parties (Li & Goodchild, 2012). Timing has been investigated as a central aspect in various emergency responses, as proven by several research in (e.g.) nuclear power plant accidents (Cipollaro & Sallus, 2009; Hanashima et al., 2017), and communities disasters (Huang et al., 2017; Kolen & van Gelder, 2018).

In line with these traits, when approaching an oil and gas (O&G) EMS, it becomes necessary to understand and analyse its socio-technical properties and their evolution and integration over time (Cabrera Aguilera et al., 2016). The standard emergency management procedures, such as ISO 22320 (2018), aim to "provide guidance for organisations to improve their handling of all types of incidents, [..] emergencies and crises". However, such claims undermine uncertainties and oversimplify the complexity of real work practices during an emergency. This type of approaches leaves room to a representation of the time which recalls an ad hoc construction, a hope, or even a mythological chimera, in the sense of its unrealistic and unlikely to be fulfilled nature (Johansson & Lundberg, 2017).

For these reasons, in exploring the resilience of EMS, the unit of analysis should be directed on investigating the socio-technical time-dependent distance between WAI and WAD. Within this specific context, the Functional Resonance Analysis Method (FRAM) is a largely adopted method for accident analyses and risk assessments in complex systems (Hollnagel, 2012) and for exploring resilience in crisis management systems (Steen & Ferreira, 2020). The FRAM has been used to capture both WAI and WAD in several types of socio-technical systems (Patriarca et al., 2020). Its functional structure inherently supports a time dimensional analysis, as previously acknowledged as well by the concept of functional signatures (Smith et al., 2018). Therefore, the FRAM becomes a good candidate for modelling time response for EMS, as for the research question of this paper: To what extent does the application of time-dependent FRAM analysis enhance response organizations' ability to understand and analyse resilience potentials in emergency response operations, hence its adaptive capacity?

This research question is answered developing an explicit time-conditional analysis based on FRAM, revising its structure to make even more explicit the role of time-critical couplings in O&G EMS. More in detail, (a) we develop a framework for FRAM which includes an explicit time dimension and facilitate the analysis of large-scale systems; and we apply the framework (b) to represent procedural work in 2nd line response (WAI), (c) and to explore how 2nd line emergency response team members adjust their performance to deal with real work conditions (WAD). All analyses are performed from the 2nd line EMS, as performed by the Operator's Association for Emergency Response (OFFB, literally in the Norwegian language: Operatørenes Forening For Beredskap) for O&G operating companies on the Norwegian continental shelf. The analysis starts with an incident analysis referred to an event that happened in Gjøa in 2017 (PSA, 2017). It then progresses using the developed framework to explore other varieties of disclosed WAD through the results of multiple interviews and organizational ethnography.

2 | THE THEORETICAL FOUNDATION

"There is a growing need for resilience in dealing with unexpected events during disasters". With these words, a recent literature review on resilience in Emergency Management (Son et al., 2020) opens a discussion on cornerstones and future research streams of the field. In this research, Emergency Management is recognized as a complex socio-technical system where four key dimensions of intervention are identified: collective sensemaking, team decision-making, harmonizing work-as-imagined and work-as-done, and interaction and coordination. Resilience is mainly enabled by adaptation and improvisation, also depending on the specific characteristics of temporality (proactive vs. reactive performance), expectancy (expected vs. unexpected events) and means for managing disruptions. Such perspective is confirmed as well by one of the first studies on

FRAM (Woltjer et al., 2009) that explains how a critical element to successfully manage (command and control) any organization is developing and updating a clear model of the interdependencies between its functional units. The contribution presents a straightforward approach to model such interdependencies with FRAM in a military environment (the DOODA loop along with the tactical and operational functions). The proposed approach might be naturally extended to any kind of complex organization requiring different levels of interventions, in line with EMS.

Work activities in the O&G industry present specific risks that have greatly increased their potential to cause harm to people, environment and corporate sustainability. Stimulated by the world's energy needs, especially in developed and growing countries, O&G technology and management practices have evolved significantly, not only to increase production and profit levels but also to reduce risks, providing dedicated interventions to improve workers' protection. Such observations remain specifically valuable for the O&G industry, where the FRAM offers the potential to understand the socio-technical nature of work, as confirmed by a number of case studies.

The FRAM has been compared with the AcciMap and the STAMP to overcome limitations that traditional models have in identifying causes of accidents within a complex socio-technical environment. The FRAM has been shown to be a valid method in this sense, as for the analysis of the Chevron Richmond refinery accident, which was originally investigated by U.S. Chemical Safety and Hazard Investigation Board (CSB) (Yousefi et al., 2018). Once evolved in an analysis method, the FRAM has been used to show how a resilience engineering approach can enhance the study of normal operations and identify performance variability that may lead to unwanted consequences, resulting in process instability (Tveiten, 2013). The case study of planning modifications to a mature offshore oil installation suggests the major usage of the FRAM for risk assessment at the organizational level.

Other studies reflect on how the human factor plays a central role to support operational safety. The FRAM has been applied to the results of ergonomic field studies describing the operations by the Brazilian Environmental Defense Centers (EDCs), identifying constraints and conflicting procedural practices (Cabrera Aguilera et al., 2016). EDCs provide response services, following oil spill accidents, rapidly organising, and executing emergency activities in affected areas to minimize the environmental and economic impacts of the event. The application shows how functional variability in planning, preparedness, execution, resources, financial and human factors affects the quality of Emergency Management. Similar results emerge from a study of maintenance in a harsh environment, which can be applicable in maritime and offshore activities (Abaei et al., 2017), providing good insights on sources of risk and on the possibility for minimizing them.

Emergency Management in the O&G industry has also been studied via quantitative extensions of the FRAM. The case study of an offshore lifting operation helped to highlight the importance of focusing on qualitative methods prior the implementation of quantitative risk analyses to estimate human error probability (HEP) (Toroody et al., 2016). The Bayesian network has been qualitatively coupled with the FRAM, and a Noisy OR-Gate model has been applied to update primary HEP for each activity, using the success likelihood index method (SLIM). Another case study of Emergency Management in a petrochemical company integrated a human reliability evaluation model (Simulator for Human Error Probability Analysis model, SHERPA) with the FRAM to assess HEP and its variability (De Felice et al., 2017). Accidents such as the Deepwater Horizon (2010) and Odebrecht NS-32 (2017) showed the existent gaps in the protection systems of offshore oil rigs, where the relationships between workers, systems, machines and environment, characterize them as well as complex socio-technical systems. A FRAM model, combined with the Analytical Hierarchy Process, helped to understand such level of complexity, showing the critical role of human factors for safe operations of workplaces, considering the natural variability that emerges from these scenarios (França et al., 2019).

In conclusion, this wide range of approaches confirms how the application of resilience engineering principles to Emergency Management has the potential to enhance the evolution of management practices in complex socio-technical environments. The O&G industry is a leading research field in these settings, as suggested by the usage of FRAM in modelling systems' properties. However, additional research streams remain open, with possible answers to be provided through the usage of the FRAM. As for the focus of this research, we aim to unveil adaptive capacities, which could be reflected in exploring the gap between WAD and WAI, a research scope largely investigated in other industries (Amorim & Pereira, 2015; Clay-Williams et al., 2015; Gattola et al., 2018). Adaptive capacities require an additional level of interaction and coordination among different functions and agents, which in large-scale systems may become overwhelming (Patriarca et al., 2018b).

Interaction and coordination become even more critical in time-critical settings. In this regard, it is worth mentioning how previous case studies on FRAM has dealt with different perspectives for time modelling. Smith, Veitch, Veitch, et al. (2018) applied FRAM for visualizing and understanding the operational dynamics of a shipping operation where the so-called "functional signatures" might provide insights into the functional dynamics of a work process. Data from an ice management ship simulator were used to demonstrate the validity of the signatures and to compare different operational approaches. On a similar concept, cellular automata have been used for describing the evolution of a steel production management problem. The results of applying this extension of FRAM provided several insights concerning the characteristics of experienced workers to handle and to manage process variability, such as harnessing, phase transformation and identification capability of critical points attaining resilient operations in terms of entropy (Hirose & Sawaragi, 2020). From the same scholars, it is worth mentioning an application of an autonomous driving technology to test the conditional driving automation or the third level of driving automation. As one of the most critical challenges in this settings refers to the smooth authority transfer from the system to human drivers in an emergency, the authors discuss the safety of authority transfer in time-critical situations. The analysis is performed via a simulator based on the FRAM, showing that the involvement of human drivers is still essential (Hirose et al., 2020).

In the process industry, an application of a propane control feed system showed that the novel concept of safety entropy, along with functional conformability, and system complexity, could help to form the qualitative understanding of the development of a system (Yang, 2020). The Q-FRAM extension proposed a numerical method for the quantification of the analysis in which key performance indicators are derived at different time moments from the FRAM model and aggregated into indexes representing resilience cornerstones (anticipate, respond, monitor, learn) (Bellini et al., 2019). Another attempt to support the definition of time-sensitive models refers to the integration of dynamic Bayesian network for quantitative resilience assessment in the FRAM. The method is demonstrated through a two-phase separator of an acid gas sweetening unit. Aspen Hysys simulator is applied to estimate the failure probabilities needed in the resilience assessment model (Zinetullina et al., 2021).

While previous literature shows an interest in FRAM time modelling, we aim to define a conceptual structure that may be used to support a systematic analysis of a dynamic EMS. In this regard, we aim to provide a FRAM representation which can consider adaptive capacities reflected on functional inter-relationships, as well as their evolution over time in different scenarios.

3 | METHODOLOGY

The methodology of this paper relies on the FRAM, whose principles are well-known to be aligned with resilience engineering (i.e. equivalence of successes and failures; approximate adjustments, emergence, functional resonance). These principles are also relevant for EMSs, as proved by the case studies already mentioned in section 2, with specific reference to the O&G sector. With the intention of exploring the gap between WAD and WAI and understanding the time-dependent effects of variability, the following section describes the model building steps used in this research to uncover functional temporality in socio-technical systems.

3.1 | Model's building steps

A FRAM model is built on four steps, where the first one reflects the proposed explicit time-dependent analysis, if compared with the original formulation (Hollnagel, 2012).

- Step 1: Functional definition. The system is described following a functional perspective, where each function refers to the activities required to produce a certain outcome. The description of the process follows six fundamental aspects, that is Input (I), Output (O), Time (T), Control (C), Precondition (P), Resource (R), graphically represented at the corner of a hexagon.
- Time is often regarded as a difficult aspect for FRAM modelling, since it may often be interpreted as one of the other aspects (e.g. it could be a time constraint, intended as a Precondition, or even a time relationship, interpretable as a Control) (Hollnagel, 2012), or it would require other detailed observations (Smith et al., 2018a).
- Therefore, rather than using time as an aspect of the FRAM hexagon, we aim to use time as a layer of analysis. This choice brings two advantages: (a) providing an evident relationship usable for time-dependent analysis (Johansson & Lundberg, 2017), while at the same time (b) reducing the graphical complexity of a large-scale FRAM model. In theory, each function should belong to a different time layer, with some of them belonging to multiple layers. This latter case applies to functions that are continuously produced or identically iterated over time (e.g. continuous or periodic monitoring). While a time dimension spans over a continuum, for practical reasons, it makes sense to group time moments in a smaller set of phases which remain relevant for the process at hand. From a technical point of view, this observation does not mean to undermine the FRAM six aspects of analysis. It is rather intended to still use the 6-th corner as an aspect for the function itself, addressing its belonging to a certain Time moment, or phase. We want to emphasize how in pragmatical terms, this idea implies that Time could be used *also* as an aspect for the function. It can be interpreted following the traditional reasoning based on (Hollnagel, 2012), when the variable cannot be expressed in terms of any other input (i.e. I, P, R, C). In addition, it could also become a "layer" (t_1, t_2,...t_n) in the sense that it represents an attribute

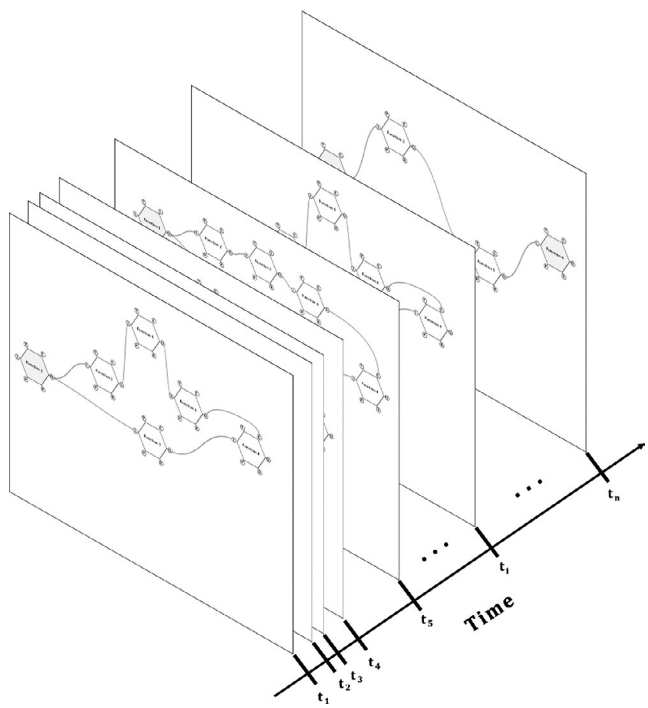

FIGURE 1 An exemplar application of the time-dependent framework for FRAM with a number n of time layers

to facilitate the identification, interpretation and graphical representation of functions in light of their temporal evolution (see Figure 1).

- Step 2: Variability identification. Each function is then studied in terms of variability. This point remains particularly relevant for WAD models, where everyday activities can be characterized by endogenous, exogenous, and/or interaction variability, as expressed by different phenotypes (e.g. timing, precision).
- Step 3: Variability aggregation. Following the variability identification step, it is then necessary to study how the upstream/downstream interaction affects system performance, exploring the model paths identified by actual or hypothetical events. In the former case, it is possible to use the model for understanding events that have already happened, while in the latter case, the analysis aims to explore other varieties of the work domain, such as worst-case scenarios. All these analyses are usually influenced by time-dependent factors, which become explicit from the initial functional modelling in the respective time layers.
- Step 4: Variability management. Variable performance, and adaptation in general, are often unavoidable in socio-technical systems. Acknowledging that they could be even encouraged to ensure systems' success, this step aims at understanding how functions are carried out in real work practices, and what should be the most effective strategy to manage—rather than reducing—their variability. To one extent, this means that WAI versus WAD deviations are not necessarily symptoms of failures. They could be needed to make the chimera of time response feasible in practice and represent sources of success, or even potential for achieving greater process efficiency. On the other hand, variable performance is not necessarily desirable in any situation, (e.g.) where it is recommended to follow a checklist. Since this research aims to use the FRAM for understanding different varieties—either experienced or imagined—of a work domain, this fourth step is intended to foster organizational learning, rather than providing stricter prescribed work tasks.

Figure 1 proposes a generic graphical representation of a FRAM model in line with the proposed steps, as emerged from a set of n time layers. Each time layer may be 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. The numerosity of layers, and the distance between them, is not fixed a priori, since it largely depends on the system at hand, and the scope of the analysis.

3.2 | WAI versus WAD

The building steps provided above allow developing time-dependent FRAM models and analysing work domains through them. The steps remain applicable for both WAI and WAD analysis.

In this setting, we aim to use them for two main purposes:

- *Developing a WAI model*. In line with the normative vision of the process as described in procedures and standards, it is possible to depict the work domain from a procedural perspective, that is how the process should be performed. This first representation has the potential to dig into procedural works, as well as to highlight the links between different procedures, uncovering potential inconsistencies or ambiguities, which sometimes concur to an unrealistic representation of work activities.
- *Developing an event-based WAD model*. Using the available WAI model, it could be possible to represent an event over it, updating it in an event-based WAD able to give evidence of the functional differences performed under specific circumstances, that is how the process was conducted within a particular event. This modelling shows adaptive capacities in practice, promoting analysis of where and how agents behaved to deal with dynamic operating environments. While this modelling can start from an accident/incident report, we prefer to use the notion of "event-based" to emphasize the possibility of adopting the same logic for any other type of low-consequence reported event, in order to increase the potential for organizational learning.

Adopting the logic described in section 3.1, it would be possible to model any work domain in light of these different sets of FRAM instantiations to capture specific time-dependent observations and variability propagation. For example, one may be interested in exploring functional variations of a certain function over time (belonging to a certain layer), as well as its cascading propagation in different time moments, or across different events (see Figure 2). This type of analysis allows a deconstructed investigation of the system, still keeping a systemic perspective able to capture both interrelationships and time dependencies.

4 | CASE STUDY

This study attempts to explore how the application of the FRAM enhances the understanding and analysis of adaptive capacities in ER operations, restricted to the 2nd line activities. The second-line emergency response (ER) operation engages various multidimensional processes, which encompasses a full spectrum of simultaneous coupled functions. In such a complex system, the time aspect is critical, when responding to an evolving incident with potential for cascading impacts. Moreover, simultaneous processes require having a common-sense, and the ability to think, interpret and analyses available data, quickly. Yet, the multidimensional processes, conducted by many actors, make the "common-sense" a more flexible term than it actually sounds. It means that the time aspect has to be understood from an interpretative perspective of each involved operator, to fully capture its underlying complexity.

The intensity of any ER operations is highly depended on the context under study. Considering the large-scale dimension of the context under investigation, the adopted context analysis encompasses a qualitative nature, on the grounds of triangulation of qualitative

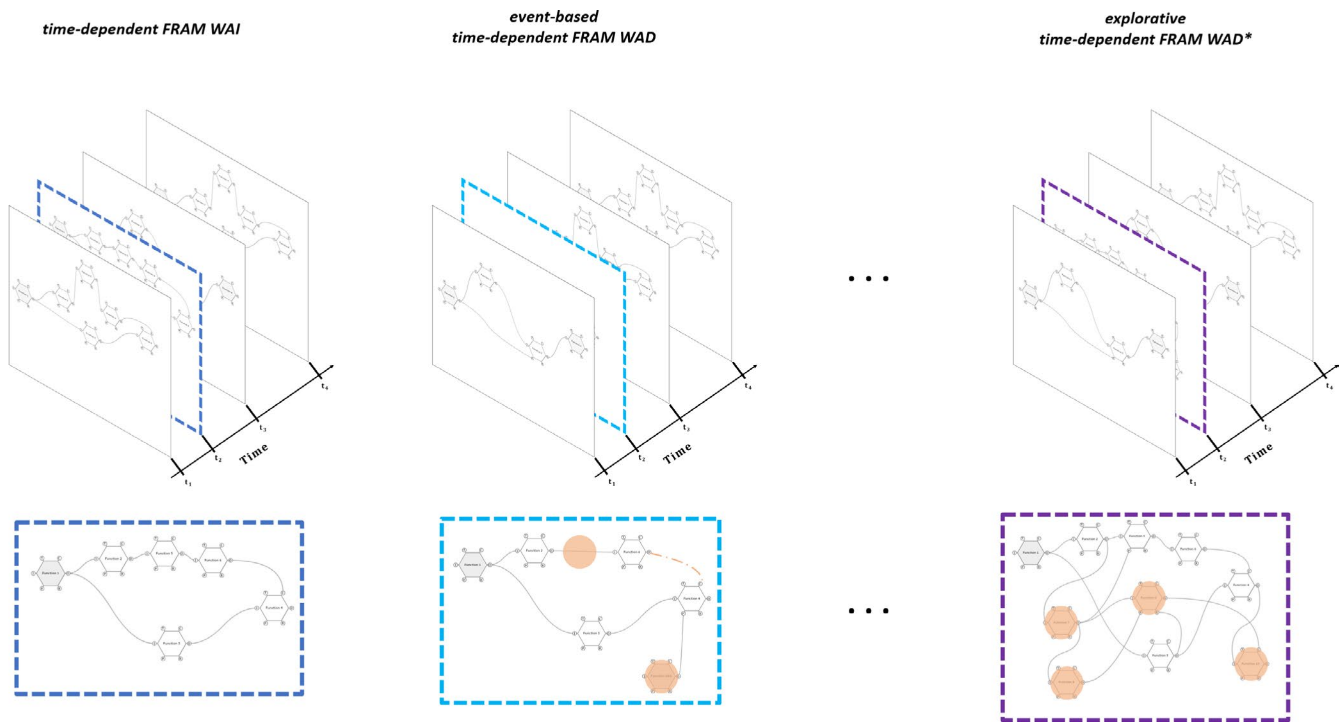

FIGURE 2 Conceptual WAI versus WAD time-dependent analysis, orange boxes symbolically represent point of differences between the models and thus are proxy measures of adaptive capacities

approaches. We used a case study as it is "suited to an exploratory examination and assists in building a supported conceptual analysis in a real-life context." (Conaty, 2012).

Our case study is related to Emergency Management operations, as conducted by the OFFB.

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 running of a range of 2nd line emergency response 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 response is also included the handling of Next-of-Kin and media inquiries. Conduction of ER is centralized at the OFFB's main office at ER room (Figure 3). Although OFFB acts as a 2nd line emergence response management, the operating companies have the overall responsibility for effective emergency response in Norway.

In the event of any types of accidents and incidents, the manager on the scene (1st line), for example Offshore Installation Manager (OIM), shall immediately inform the 2nd line ER manager. After this initial notification, the 2nd line ER operations instantiates. Different types of functions, including the human, technological and organizational form, are involved in the operations in the ER room.

Regarding *human functions*, besides the ER manager (ERM), five other experts assist entire ER operation, on a rotating duty. Emergency Response Manager (ERM): The ERM is responsible for initiating mobilization/notification of ER Team, 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 also has 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 ER team and the installation owner. COS's tasks are mainly coordination of the ER team and conducting situational awareness with the ER team. 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 third member of ER team is the authority coordinator (AC), who is responsible for initiating mobilization and notification of the Petroleum Safety Authority Norway (PSA), Police, and the Norwegian Clean Seas Association for Operating Companies (NOFO), as well as the Norwegian Coastal Administration (NCA). The next one, personnel coordinator (PC), has main responsible for initiating mobilization and notification of the On-Call Physician, contingency physician, Next-of-Kin Call centre, operators centre for evacuees and Next-of-Kin, operator HR representative and the installation owner Human Resources (HR) representative. Finally, the information coordinator (IC) is responsible for initiating mobilization and notification of the media/communication response team leader

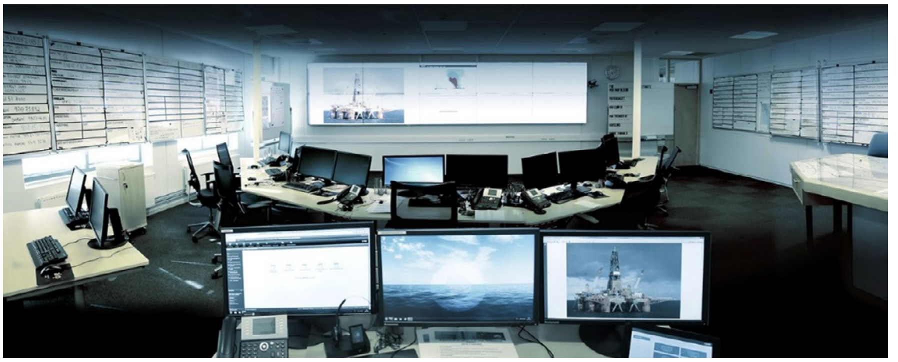

FIGURE 3 The emergency response room (ERR) at the OFFB

for the operators and the liaison representative from the installation owner. IC is also responsible for notification and following up the contractors.

Concerning the *technological function*, OFFB utilizes the Crisis and Incident Management (CIM) software, as a communication platform, to share information simultaneously, alerting roles, action and decisions made, with the relevant stakeholders. The concerned parties have role-specific access to OFFB's CIM system. The shared statuses (situational information) logs and updates and provides every operator (parties) get insight into the whole operational picture.

Regarding *organizational functions*, OFFB as the core system per se provides training activities for the ER team, as well as additional support, for example technical support, data, telecom, catering and security. Developing best practice documents and maintain its quality, developing networks, updating procedures are among the other tasks of the OFFB, as represented by the respective organizational functions.

4.2 | Data collection

As mentioned earlier, the data collection for this study relied on multiple data sources to ensure a comprehensive and detailed information picture. We conducted task analysis, using best practice documents and procedures in OFFB. The results from the document analysis, then, were integrated with the contributions of the domain experts, that is to say, ER team at OFFB, through in-depth interviews. Finally, we applied an ethnographic approach to understanding the working environment, to translate our empirical findings through the lens of a 2nd line ER operational context.

4.2.1 | Document analysis

We studied the 2nd line Emergency Response Plan developed by OFFB. The document provides a basis for OFFB's 2nd line proactive management of emergencies in close cooperation with its member in the 1st and 3rd line activities, as well as with other parties involved. Our focus was on understanding how emergency response is designed (WAI), how the coordination process is organized, which roles and activities are defined and how these roles interplay with each other. We have also studied two investigation reports on the Gjøa incident on 21 June 2017, where OFFB had a central 2nd line ER operational role. The first report was prepared by OFFB as an internal report about the ER operation. The second report developed by the Petroleum Safety Authority Norway (PSA), where the focus of the investigation was on the incident and how the operators managed it at the scene (the 1st line activities). Exploring these investigation reports provided us insight about how different functions (event-based WAD), involved with emergency response activities.

4.2.2 | Semi-structured interviews

We conducted nine semi-structured interviews during January–March. 2020, with an average duration of 60 min each. Participants included members in the ER team on a rotating duty at OFFB who had a crucial role in the coordination activity in an emergency. As we were more concern about having in-depth discussions, rather than a direct question and answer format, we did not strictly follow our list of questions, which was prepared in advance. Preferably, we used an open-ended question style, while we attempted to link our topics of interest to the interviewee's context. FRAM, and its terminology, inspired us to develop a set of trigger-questions to use during the interviews:

- What are *your tasks* during the ER process? What are the essential functions? Are any *resource* required?
- What are *the preconditions* for acting as the function requires?
- Does the OFFB's guidance cover all aspects of your tasks? What is missing?
- Is there any *variation* associated with your tasks?
- Is the best way to do your task the same as the way described in the *procedure*? Is this the way you were trained in?
- What are the factors that contribute to *successful operations*, and how can they be applied?
- Tell us about how might stress and time pressure affect your *performance* in daily activities.

The interviews were conceived and managed in line with LeCompte (2000, p.148) guidelines. This latter research proposes nine steps for managing qualitative data, including (1) recording of all data materials; (2) putting all interview notes into a file, based on their dates of gathering; (3) designing and implementing a system for logging interviews, we have done it by labelling them to which agent; (4 and 5) categorizing and marking all documents, as we have created a data file schema for four phases of ER operation; (6) establishing the safe storage of all materials, we have recorded and transcript interviews; (7) creating a table of contents for all data; (8) identifying missing data by controlling if data were collected to answer the research questions. In this regard, we have developed a series of questions in advance and shared it with interviewees, to allowing them to reflect on the topics; and (9) returning to the field to gather additional data to fill gaps data gathering. Concerning this point, we have utilized an ethnographic research approach.

4.2.3 | Ethnographic research

According to Yin (1994), ethnography approach requires that researcher "involves a field-based study long enough to surface people's everyday norms, rituals and routines in detail" (p. 17). As an ethnographer in the 2nd line ER context, the first author of this paper was spending her sabbatical year in OFFB to conduct field research on resilience in emergency management. Conducting ethnographic research has its own challenges (Lindberg & Eule, 2020; Yanow, 2012). Unwritten and unvoiced, without a single word, the ethnographic researcher, almost always hears a voice, to remind him/her of being an "outsider," from an academic world, theorizing on reality when attaining an operation without understanding the context. In such a situation, it is often difficult to ask a question or make a comment. As Watson (2012) suggests, anyone who conducts an organizational ethnography should have "[...] a good grasp of the sociological, anthropological, psychological and methodological thinking which has informed the study of organisations so far." Accordingly, we ensured our position in OFFB by reminding the staffs of our role, which was to observe and learn about the ER process, about how "work is done" not to evaluate it.

Having said that, our observation through a "systematic description of the events, behaviours, and artefacts of a social setting" (Marshall & Rossman, 1999, p.79), when joining in different ER exercises, provided us with a unique opportunity to understand the working environment, to translate our empirical findings through the lens of an ER operational context.

4.3 | Time-dependent FRAM modelling

The results from the interviews, as well as our findings from document analysis and ethnographic research, provided insights to develop the FRAM models used for the analysis. In presenting our FRAM, we used colours to code the agents involved in the ER operation as follows:

1. Emergency Response Manager (ERM) (Purple)
2. Chief of Staff (COS) (Green)
3. Logistics coordinator (LC) (Blue)
4. Authority coordinator (AC) (Yellow)
5. Personnel coordinator (PC) (Grey)
6. Information coordinator (IC) (Red)

This section provides evidence of the suggested methodology, as indicated in Section 3.2.

4.3.1 | Time-dependent Work-As-Imagined (WAI)

All of the agents in the ER team (described in the forward of Section 4.3) are involved in an ER operation. Depending on which time the event (incident/accident), takes place (during or after the working hours), the ER operation starts either at the ER centre, that is OFFB's location, or the whole ER team will be gathered at ER centre, after first notification. The ER operations generally involve the following four phases: mobilizing; alert/warning; combat (the handling phase); and the normalization phase. These latter represent the four main layers of analysis of the developed FRAM time-dependent model.

The entire WAI model for each phase is sketched in Figure 4. To ensure conciseness and representativeness of the analysis, only the first layer, referred to the phase of mobilizing, is presented separately and discussed more in-depth in terms of its functional properties (see Figure 5). For the consistency, the model is discussed using specific aspects for functions as follows: <Name of Function>, 'name of aspect'.

4.3.2 | The first phase: Mobilizing

To describe this phase through the FRAM approach, we assume that the incident occurs during the working hours, and the ER room is ready to be utilized. The ER room is prepared when the following tasks are performed:

- the ventilation system is switched on
- the lights are turned on, curtains are drawn, and the entrance area is shielded
- ERM is notified that the first person has arrived in the ER room (centre)
- the phones are ready, that is, no phones in the ER room are set up with the hidden number
- the essential objects, such as paper and pencils, are available

The procedure (WAI) expects that the personnel involved in ER operation are available and ready to conduct their tasks timely, according to the best practice procedures, they are in a good mental and physical health condition, when joining ER operation.

Mobilization phase starts immediately after the first alert (by phone) when ERM <*Receive the first notice*> from the offshore

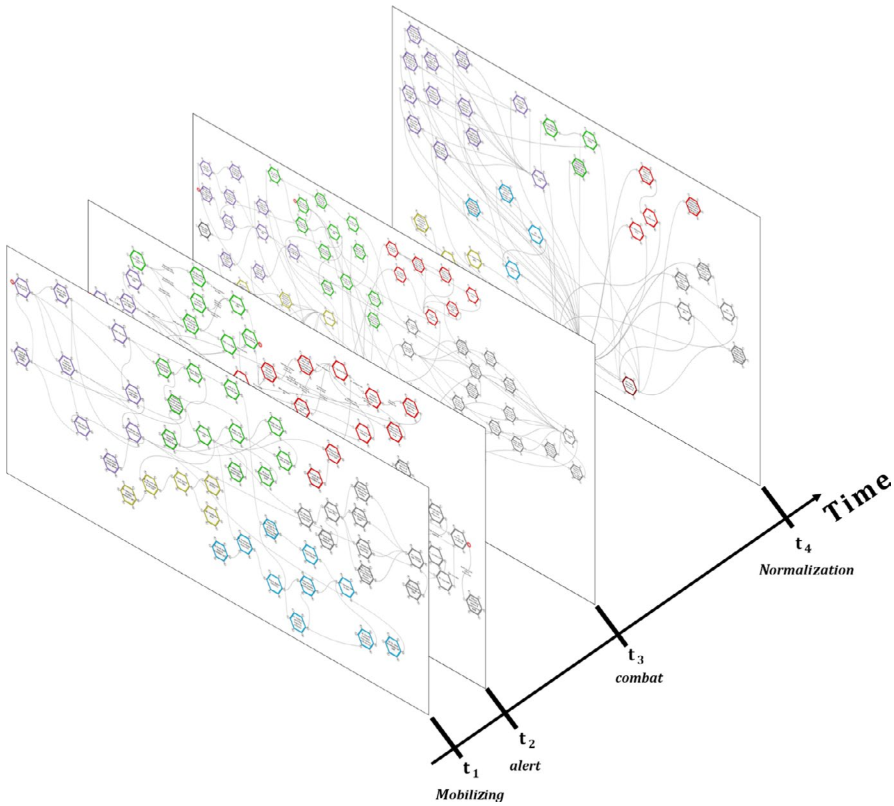

FIGURE 4 The time-dependent WAI model of emergency response room in action over the four time layers: mobilizing, alert, combat and normalization

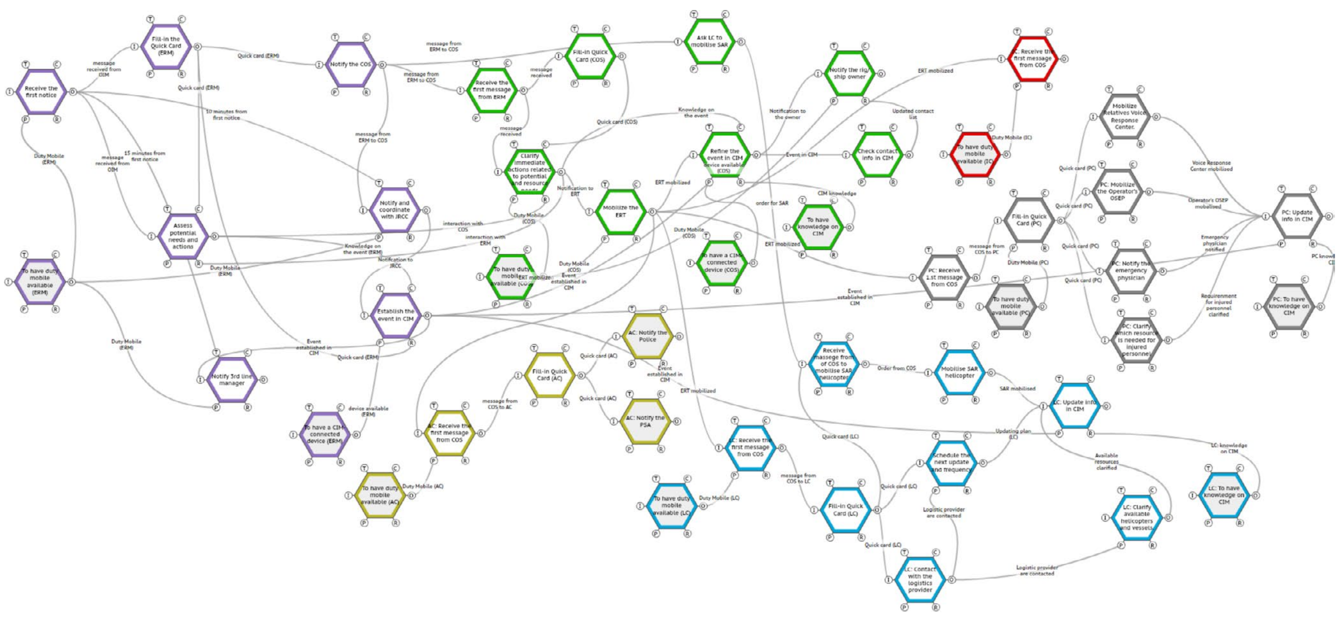

FIGURE 5 The WAI model of the first layer (first phase: t_1 - mobilizing)

installation manager (OIM), rig manager or the drilling supervisor. Based on "message received from OIM," ERM perform the functions *<Assess potential needs and actions>* and *<Fill-in the Quick Card (ERM)>*. ERM uses the information from "Quick card (ERM)" to *<Notify the COS>* and further *<Notify and coordinate with JRCC>*. The Joint Rescue Coordination Centres (JRCC) is one of the OFFB's partners who co-operates with ER during search and rescue operations. ERM then *<Establish the event in CIM>* and updates information in CIM when he/she performs any tasks, for instance, the "Notification to JRCC." The description of the *<Establish the event in CIM>* function, let us call it for now as CIM for simplicity, points to four other related functions, from its aspects Input, Resources, Precondition and Control. For instance, the Input to CIM is the "Notification to JRCC," a performed task and the result (Output) of *<Notify and coordinate with JRCC>*.

The "Quick card (ERM)" which is the Output from the *<Fill-in the Quick Card (ERM)>* function is linked as the Resource in CIM. The

Output of <*To have a CIM-connected device (ERM)*> function is the Precondition for CIM, which can be considered as a background function, which we do not describe further in our analysis. The Control aspect of CIM is the Output of function <*Assess potential needs and actions*> which supervises that the event is adequately established in CIM, in a way that all of the involved parties who have access to the CIM get the same picture of the event as ERM has understood.

The "message from ERM to COS" uses by COS as an Input to <*Fill-in Quick Card (COS)*>. The Output of this function will be further used to <*Clarify immediate actions related to potential and resource needs*>. The result (Output) of this function, that is "Notification to ERT," is used in giving notice to ER team's four agents and <*Mobilise the ER team*>, as well as the "Knowledge on the event" which will be further used in <*Interaction with ERM*> in assessing the situation.

This phase ends when the coordination of response activities between ER manager and 3rd line is complete and the ER agents Fill-in their Quick Cards based on the information from COS and mobilize their stakeholders, which is the connection with the other time layers (Section 4.1). The functions related to CIM are as well linked to multiple layers, since already in this early phase, the role of CIM starts becoming central as a knowledge repository.

4.3.3 | The second phase: Alert

In the second phase, the alert, ER coordinators shall notify all of the relevant actors, parties and authorities about the accident/incident. For instance, information coordinator (IC <*Contact Operators Media/communication Response Team*> to create and coordinate an effective information flow (thorough a common situational awareness) to the media representative (PR) or the 3rd line's Media Response Team. The logistic coordinator (LC), <*Consult with JRCC about resource allocation*> to decide whether there is a need to <*Mobilise additional resources*>. When these actions were taken, before moving to the next phase, (combat), <*ERM: Conduct 1st meeting for situational Assessment. (SA)*>, where all of the agents share their concerns. In the first meeting, ER team should conduct a worst-case assessment and identify the potential of the emergency to provide proactive advice to the installation on possible remedial actions and support measures, as well as make a plan for the next move. A technological agent, CIM, which is represented via technological functions, has a critical role in ER operation. It acts as a communication platform and is responsible for providing a common situational picture, by sharing information simultaneously, alerting tasks, and decisions made, with the relevant stakeholders, during operation. The Output of any function, taken action by agents (e.g. <*ERM: update CIM*>; <*COS: update CIM*>; <*AC: update CIM*>) shall be used as the input in <*CIM: Provide information*>. In this way, the dynamic of situation and decision made, provide updated alerting processes, through "Information from CIM," which in turn enhances the efficiency of the ER operation.

4.3.4 | The third phase: Combat

Then, after notifications, joining the first meeting, making the next move plan and updating CIM, the ER handling (combat) begins. Routinely, in this phase, resources are provided to deal with the incident following the action plan, which is the Output of joining the first meeting (second phase). The action plan includes carrying out combat, search and rescue, evacuation, environment protection and personnel care to deal with the event. Some of the combat-related tasks, conducted with the ER agents are as follows: the personnel coordinator (PC) should <*Establish contact & coordinate actions with HR 3rd line (operators & owner)*> and <*Send the POB list to the relevant stakeholders*>. He/she should also <*Maintain contact with Next of Kin's telephone centre*>. The logistic coordinator (LC) should <*Mobilise helicopters following action plan (1st meeting)*> and <*Inform relevant helicopter company about changing scheduled trips*>. Notification and updating the authorities (e.g. Petroleum Safety Authority (PSA) by AC (authority coordinator) is also a crucial part of this phase. Tasks include (e.g.) <*Update the PSA about the sit. Regularly*>, <*Apply for expansion of the safety zone: whether it is relevant*> and <*Update police if criminal act*>. There are many other actions to be taken in this phase. The dynamic of the situation creates new actions and new information which should be shared further with relevant stakeholders. The role of information coordinator (IC) in this regard is to ensure that information is properly shared, by, (e.g.) <*Keep the 3rd line up to date with status, updates every 30 min*>. Based on the last information, when <*IC: Check updated information on CIM*>, IC provides holding statement (HS) and <*Send HS to 3rd line*>. However, while IC provides HS, it should be verified by ERM <*Send Holding Statement to ERM for approval*> (as from phase two), before it is sent to the 3rd line. The role of Chief of Staff (COS) is to ensure that the ER agents, involved in the 2nd line, have an updated and common situational picture. The critical aspect of the COS is that he/she should have comprehensive knowledge of the tasks of the individual function of the ER team. COS should also <*Consult with ERM about the need for a new situational assessment*> and <*Assess OIM has adequate ER resources*>, for instance, SAR helicopter, Evacuation centre (OSEP), a location for physically uninjured persons who have been involved in an incident. The performed tasks should be registered in the CIM, continuously by the other agents, as represented by continuous functions over each layer.

How long does it takes to handle the situation is quite a context depended matter regarding the scope of the event. When there is a common ground between 1st, 2nd and 3rd line ER authorities confirming that the emerging situation is over, this phase ends, at least for the 2nd line.

4.3.5 | The fourth phase: Normalization

In the normalization phase, the focus shifted quite fast from responding to the event to bounce back to a normal situation. The critical tasks of ERM are to <*Verify with 1st line that situation is under control*>, <*Verify with 3rd line any support needed from 2nd line*>,

FIGURE 6 Location of the Gjøa site used in the event analysis

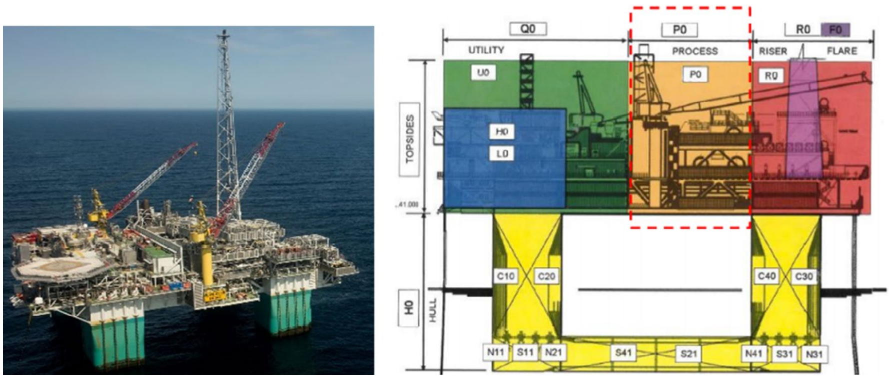

FIGURE 7 The condensate leak location "area P0" (PSA., 2017, p. 9)

and <*Ensure Police/PSA approval for a transition to normalisation*>. It means that from an operational point of view it should be a common ground between all of the ER agencies about the transition to normal phase. When there is a mutual agreement about this transition, ERM <*Organise and conduct debriefing ERT*>.

For the 2nd line ER, this phase includes debriefing and sharing experience, and the evaluation of response activities according to best practices. A collective organizational function, related to debriefing, that is <*ER Team: debriefing meeting*> ensures that ER agents have a platform to share their experience about ER operation. The Output from this function provides "Lessons from ER operation." These lessons will ideally enhance improving the best practice procedures to deal with the next emerging situation through an organizational learning cycle.

4.3.6 | Time-dependent event-based WAD FRAM—Gjøa event

The event is about an incident that occurred in the Gjøa process module (see Figure 6). The incident was detected when the plant operator made a routine inspection tour of the lower deck (Figure 7).

There were 49 personnel on board (POB) at the time of the incident. They were mustered after 11 min after the first notification. The ER organization on Gjøa (1st line) was mobilized immediately, and Engie (the operator, 3rd line) activated its ER team at Stavanger (OFFB, 2nd line). The detail of the incident is as follow (PSA, 2017, p. 3):

> At 20.01 on 21 June 2017, the plant operator discovered a leak on the lower deck in the Gjøa process module. This proved to be a condensate leak from a fractured weld on a pipe nozzle installed on a condensate pump connected to the gas recompression system. The plant operator went to the leak site and tried to close a valve on the same nozzle, and was then exposed to condensate. The operator immediately notified the CCR[1] about the leak. Soon afterwards, at 20.03, the deluge system was activated following confirmed gas detection in the area." ESD[2] was activated,

followed by a general alarm, pressure blowdown and mustering in accordance with the alarm instructions. [...] Several attempts to close the ESV[3] were made from the CCR without success. The operators then decided to open a manual valve on the deck above the leak, which was connected to the closed drain. [...] During the incident, it also became clear than another ESV – in this case for blowdown – had failed to open towards the flare as intended. This affected the time it took to depressurise the process plant.

The offshore installation manager (OIM) at Gjøa notified the 2nd line Emergency Response Manager (ERM) in OFFB about the incident at 20.22 on 21 June 2017. Soon afterwards, the 2nd line ER operation was started in the ER room in Stavanger, OFFB's location. What follows describe how the ER operation was conducted (WAD) in the ER room.

Timeline

Figure 8 shows the timeline of main undertaken activities (WAD), based on OFFB's internal reports.

Functional description of the Work-As-Done

A wide variety of response actions were carried out by the OFFB's ER team, according to guidelines and instructions. The data collection supported capturing data on function activations, as well as process' variability, in line with the internal ER report developed by OFFB in 2017. This section provides a functional description of the work process, intended to capture both the identification of functions, their variability and their aggregation through a qualitative research lens.

The 2nd line ER operation started when ERM <*Receive the first notice*> from CCR (Central Control Room- 1st line), at 20:12 and <*Receive the first notice*> from OIM (1st line) at 20.14. ERM and OIM discussed the situation at hand (gas leak), and the potential consequences, including injuries and fire, for approximately 3 min. This rather short discussion provided insights about the incident. OIM informed ERM that there were 49 persons on board (POB). The conversation with the OIM provided ERM with enough basis for further decisions regarding the resource assessment (<*Assess potential needs and actions*>). ERM noted the incident information in his notebook and used the info in the Quick Card (<*Fill-in the Quick Card (ERM)*>). Based on information in "Quick card (ERM)," a few minutes later, ERM <*Notify the COS*> and conduct a joint situational assessment (SA) (i.e. <*Clarify immediate actions related to potential and resource needs*>). The Output of holding a joint SA was an "interaction with ERM," which resulted in a list of actions to be taken by the ER team (four agents, see Section 4.2.1). They (ERM and COS) considered the potential of the incident as significant and that the course of events could rapidly escalate. They made, therefore, a proactive decision both in terms of evacuation with enough SAR resources, and mobilization of the Operators Evacuees and Next-of-Kin Reception

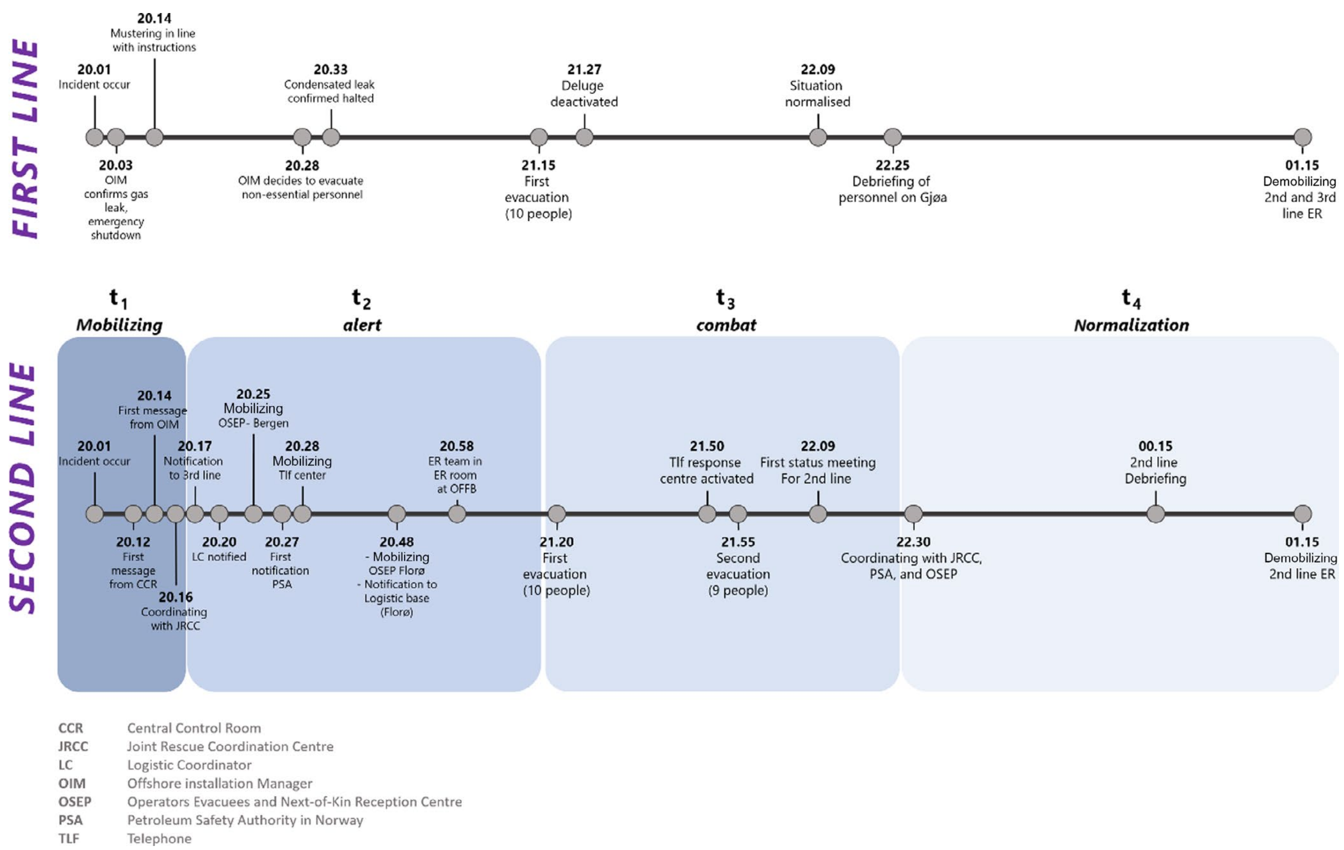

FIGURE 8 Timeline for 1st line (up) and 2nd (down) response to the Gjøa event. The focus of the study is on the 2nd line activities as performed by OFFB

Centre (OSEP) in Bergen and Florø, as well as voice response centre. Moreover, ERM and COS agreed that COS should ask the ER team (four agents, Section 4.2.1) to conduct the following tasks:

- ERM coordinate with JRCC, including access to Helicopter resources (Sea King)
- Logistic coordinator (LC) to call emergency services at Logistic and Base Florø.
- Authority coordinator (AC) notify the PSA, before she left her home, to attend ER room in OFFB's location.
- Personal coordinator (PC) mobilize OSEP in Bergen (the first prioritisation) and OSEP Florø, as well as voice response centre.
- Information coordinator (IC) was instructed to await notification of Media Response Team (MRT) until ERM/COS notified. ERM scrambled Sea King from JRCC and Search and Rescue helicopter (SAR) Oseberg and initiated evacuation.

Note that Gjøa incident occurred outside the regular working hours, which means that a part of mobilizing activities was conducted elsewhere until all of the ER team members gathered at ER room in OFFB's location. ERM registered information about the incident on CIM (ERM <*Establish the event in CIM*>), at home, before driving towards OFFB's location, which made it available to everyone (who has access to CIM) at an early stage of ER operation. This point might highlight that the need for adjusting WAI depends highly on the situation.

The notifications (second phase) were carried out following the plan and requirements (WAI). Regarding this incident, the sequence of ER operation developed rather rapidly concerning the actual event (gas leakage), the distance from Gjøa installation to land and evacuation of staff to the mainland. Regarding its cascading potential, many decisions were made, proactively (see Figure 5).

According to the OFFB's internal report, DaWinci Services (a Logistics Management Software that caters for Planning, Transportation Management and Personnel Logistics), did not function optimally, in terms of providing information for the personal coordinator (PC), (e.g.) information about the flights with evacuees was not available for PC. PC mobilized the Voice response centre (<*Mobilise Relatives Voice Response centre*>) with a manager and four operators. They were regularly updated by PC (<*Maintain contact with Next of Kin's telephone centre*>. The decision not to mobilize more operators was based on the fact that all the evacuees called home to their relatives. The telephone number was publicly published on TV2's pages (the Norwegian television channel) where they covered the incident at Gjøa. This act was not according to the WAI procedures, highlights how WAI is modified by decision-maker, in terms of new practices.

In the third phase, because of the challenges with the ESD system, 19 people were evacuated to the land. For evacuation, as mentioned earlier, two helicopters were mobilized, a Sea King and a SAR machine from Oseberg. Besides, two ships in the vicinity offered assistance. The first part of evacuation was at (21:15–20), for ten persons, and the second part at 21:55, for nine persons. The operators centre for evacuated personnel and Next-of-Kin (OSEP) in Florø was mobilized and received the 19 evacuated people.

OSEP Florø was mobilized at 20:48 by PC (<*PC: Mobilise the Operator's OSEP*>). The OSEP leader managed to stay in place at the heliport in Florø to receive the first flight with ten evacuees, despite a short mobilization time. They kept the personnel in the waiting room until flight number two arrived with 9 people, before being transported to the Quality hotel for registration, getting clothes and food. When the capacity of the Quality hotel as an evacuation centre was reached, the evacuees were transported to Comfort hotel to get rooms for accommodation. Moreover, during the evacuation, PC maintained communication with the HR in the 3rd line and OSEP leader at Florø (<*Coordinate with 3rd line & other relevant parties about evacuees*>).

An extended status meeting was held at 22:09 where ER team went through the status and the tasks that had been done and the way forward, (following WAI procedure which supposes that: <*ERM: Conduct 1st meeting for situational assessment (SA)*>. All the agents joined the first meeting (e.g. <*IC: Join 1st SA meeting*>, <*PC: Join 1st SA meeting*>). Registration of information at CIM (e.g. <*ERM: update CIM*>; <*COS: update CIM*>; <*AC: update CIM*>, <*PC: update CIM*>), led to a collective situational awareness in all of the three lines of ER agents (<*CIM: Provide information*>). However, in WAD, due to the intensity of the situation and the number of activities, it turned out that it was difficult to register performed tasks directly into the CIM. Alternatively, the ER agent noted their activities on paper, continuously, and record them into the CIM afterwards. Moreover, the OSEP log was not visible in the 2nd line, which unlabelled 2nd line to see what was performed through CIM.

Regarding the communication between the lines and other actors, the summary from the lines and parties involved after the incident indicated that there was effective communication between the lines and with other actors (according to the OFFB's report). For instance, during the event, 2nd line received information from JRCC that they had received a request from TV2 who had received information that there was a gas accident in the North Sea. JRCC requested a number that they could give to the media for media coordination. When contacted to the 3rd line, they had no number yet ready. They asked 2nd line to wait for 15 min, and this is somewhat interpretable as "too long time" an aggregated functional variability when coming to performance variability when the media demanded a quick response.

The coordination of media inquiries between the PSA, Police and JRCC must come as an early action in the third line, and the media numbers must be out early. The internal report indicates that the interaction between authorities (the PSA and Police) was maintained by authority coordinator (AC), during the ER operation. We can find many coupled functions in coordinated activities between relevant authorities. For instance, JRCC informed several police districts, which in turn then contacted 2nd line on ERM's emergency telephone. This indicates that the effectiveness of ER operation depends not only on the three lines of ER but also how they communicate and maintain information sharing with the other involved organizations.

Transition to the fourth phase (Normalization) started at 22:30. During this phase, many activities were conducted, including coordinating between JRCC, PSA and OSEP. ERM Organized and conducted a debriefing with the 3rd line (<*Verify with 3rd line any support needed from 2nd line*>). He/She also clarified the situation with the 1st line (<*Verify with 1st line that situation is under control*>). Afterwards, ERM conducted a debriefing with the ER team (<*Organise and conduct debriefing ERT*>) at 00:15. In the 30 min debriefing, the ER team shared their experience regarding ER operation. The comments were later used to provide an internal evaluation report. At 00:45, the 2nd line ER at OFFB location was demobilized.

5 | DISCUSSION

In the previous sections, a FRAM-based structure has been developed to understand and analyse the potential of resilience in an ER operation. The proposed structure allows reflecting on adaptive capacities in functional inter-relationships, as well as their evolution over time in different emergency scenarios (WAD). Time matters greatly when it comes to protecting lives, environment, properties and reputation, from (e.g.) notifications of an occurrence to engaging the response team, towards confirming decisions regarding mobilizing, allocating and coordinating resources (Pollock & Steen, 2020; Wilkinson et al., 2019). As the time pressure and uncertainty associated with ER operation increases, the capability to anticipate and monitoring become increasingly critical, and therefore, understanding how to foster these capacities within the system becomes vital. The 2nd line ER operation starts with receiving a call from the first line (e.g. the Offshore Installation Manager (OIM)).

The FRAM model allowed us to follow the line of impacts, to understand the nitty-gritty of the working activities, as well as to explore the results an activity produces and how they relate to the entire working process. Using FRAM creates thus opportunities to delve into the activities as carried out by operators in ideal (WAI), and real (WAD) operational contexts, with the ultimate purpose of improving the efficiency of the EMS system. From a modelling perspective, this means that the complete FRAM model can be split in many instantiations, as per the scope of the specific analysis. Furthermore, the layered structure supports the creation of multiple instantiations from the original model, to depict additional variations, propagations, and combinations of variability.

Moreover, managing the complexity of the ER operation requires that all of the involved agencies proactively adopt a transparent approach to joint decision-making. It also highlights the most crucial aspect of the first function, whose Precondition makes explicit the terms and the context of a possible incident. In a collective multi-agency operation that involves with time pressure and high level of uncertainty, an efficient feedback mechanism is vital to ensure a collective situational awareness. Reliable communication is a key element in such a mechanism. One of the interview participants made the following points in highlighting the role of communication and how it propagates at a functional level:

> [..] the first call from OIM (the Offshore Installation Manager) involves with one-way sharing of information. It is what shapes the response operation. The information from the OIM is rather short, as he might be under a huge amount of stress, partly caused by the incident, partly by the uncertainty involved with the situation. He (OIM) knows something, but not the whole picture of the situation at hand. It is therefore crucial that emergency response manager (ERM) who receive the first call is able to ask appropriate questions to understand the situation. This, on the other hand, depends on how much training you have and what life experience you have. I have many experiences regarding misunderstandings. For example, you have the abbreviated language, with a lot of professional content, which sends to the recipients and presume that the recipient has a full understanding of the content. This is a wrong assumption, and should not take it for granted.

When extending the analysis to systemic aspects, we asked the participants to provide us with alternatives to enhancing resilience in ER operations, regarding communication management:

> [..] You must have "affirmative communication." So, when the platform manager calls, you ask again. Then I ensure that I understood him correctly, for example, a suicide case on board. What he has done about it, who has been notified, etc. After his information, I repeat what he said to ensure a common understanding.

This drives back to the FRAM model, showing the need for feedback loops, and a Control mechanism to be put in place to ensure the feasibility of the proposed approach.

As casualty data share by OIM, do this give a clue to the cause of the incident? Could other complexities be ruled out, in particular when the cues are faint and difficult to be shared literally? Would the situation get escalated? These are some of the considerations the ERM had to contend with in planning a promply response process, based on the data from the first call. Our interview process inspired by FRAM terminology enabled us to focus on different aspects providing a deeper still systemic understanding of the context of ER operations. One of the areas of concern which we were very keen to get some comments from our participants was the gap between WAD and WAI, as explicitly addressed in the different model settings. As an example, one of participant proudly mentioned the following, in supporting the functional variabilities (WAD) we identified in previous sections:

> The role of experience in tackling stress and ability to improvise is not a thing that you obtain in a short time. You have to understand that any ER operation is different in somehow. So, the things that you learn

> through 120 exercises give you something to go through… It's something you get in your blood, a kind of positive manipulation. Yes, it's also a bit of personality. Because you, in your team, have some people who are very process-oriented, and procedure-oriented. They say to you that I'm going to act by the book. They panic if they can't find a regulatory framework to look for. Also, you have someone who is used to taking things on the kick. Based on Gut Feeling.

This comment denotes that acting resiliently, in terms of improvisation, requires inter-organizational collaboration (Kristiansen et al., 2019) and organizational support, for example systematic tools and information sharing and training, and authorization. A potential conflict here is the imperative of using standard procedures and instructions in one hand, performance variability and the need for improvisation on a continuing basis, in the other. Defining improvisation as a deviation from standard procedures leads to less motivation and room to spontaneity and improvisation. The dynamic and communication in four phases of ER operation affects operation, through sensemaking, sharing information and joint decision-making. These factors are inherently related to organizational culture.

ER operation is a dynamic process, hence conducting a FRAM analysis of an EMS is a challenging task. The challenges emerge because this type of analysis pushes the analysts out of the comfort zone. In line with its bottom-up explorative dimension, the FRAM aims at understanding the details of real emergency management activities. It forces the analyst to move away from over-simplistically varieties of how operators deal with an emergency and orchestrate various organizations.

In reality, many hazards of unforeseen intensity might challenge the imagined underlying assumptions of work as described in procedures or regulations. In the standard emergency management procedures, a description of how the various functions behave, how their couplings are interlinked and how the potential variability embedded in each function reverberates over time through the system is missing. This "lack" constrains our understanding of how an EMS works, or it is supposed to work. It may also hamper the decision-making ability of the ER system in highly uncertain situations, such as an explosion in an oil installation.

Analysing a complex system such as an EMS mandates to acknowledge that real work is complex, and operators adjust the way they conduct their tasks continuously, sometimes they do it without even acknowledging it. Adaptation is thus required specifically when time constraints emerge, and it dominates the way ER is performed. The proposed explicit time-dependent analysis supports such understanding, shedding lights on functional reverberations between imagined and real work activities.

Nevertheless, we want to remark that the proposed FRAM modelling does not represent a solution per se. As suggested by the results of this research, it is rather a mean to ask better questions, a support tool to understand how decisions adapt and propagate over time, their functional properties and their potential to become critical under certain scenarios. This is somehow leading to the idea of using the FRAM to build scenario-based training (Wachs et al., 2019) or to use it as a way to manage the way training is conducted (Smith, Veitch, Khan, et al., 2018).

More in general, the WAI-WAD time-dependent formulation opens the path to elicit knowledge systematically from both reported events and informal discussion. The proposed modelling approach aims at giving voice to operators in telling their second stories, in creating opportunities for understanding the offstage of real operations. We believe that the efforts of developing a WAI model, prior to coming to WAD, is a choice that gives evidence of what documental material and managerial expectations or beliefs are expected to cover and what they actually do, or do not. It represents thus an efficient opportunity to reduce organizational dissonance (Vanderhaegen & Carsten, 2017) when complementing it through many reported events or many feedbacks from people (Steen & Morsut, 2020).

6 | CONCLUSION

This work builds on the assumption that analysing the gap between imagined and actual work practices can be instrumental towards a deeper understanding of how ER operations may succeed or fail under varying conditions. Reaching a level of detail which supports an in-depth understanding of real operations in FRAM was a time-consuming and not even complete effort. As already discussed, any model is—by definition—an incomplete artefact. Rather, its usage as a comparison tool between WAI and WAD provides benefits to foster organizational learning, through incremental efforts to incorporate individual knowledge and experiences. Here, learning is about how ER team member translates their experience from a conducted ER operation into useful knowledge for future events. It is also related to the action that OFFB, as an organization, will take based on its newly acquired knowledge (e.g. updating procedures, implementing new tools and developing scenario-based training activities).

When coming to detailed modelling choices of the paper, we adopted some simplifications. As a result, our analysis is carried on some underlying assumptions. For example, as a complex sociotechnical system, the efficiency of an EMS depends on the adequacy of the necessary resources (e.g. human resource, information sharing system, monitoring tools, etc.). In this work, we assumed that these resources are available with the characteristics required for successful functionality. For instance, we made assumptions that all of the involved ER team members are mentally and physically prepared to join ER operation, the infrastructure functions as it should, the relevant agencies have access to CIM in any circumstance, etc. However, in reality (WAD), we get to the point where the complexity and dynamics seem to be inescapable. In such a setting, additional small variations in functions might affect the entire ER operation through highly interdependent system elements. Thus, these assumptions should not be taken for granted and included in worst-case scenarios models. Future research efforts could also focus on an additional level of details for technical artifacts from a joint-cognitive dimension of analysis, fully exploring the role of artifacts such as the CIM in ER, regarded in this work as a black box, even exploring multiple levels of abstractions in the representation (Patriarca et al., 2017).

From a methodological perspective, the FRAM has been recognized to be graphically overwhelming in case of large-scale models, with limited potential for traditional qualitative techniques like the ones adopted in this paper. In this sense, the qualitative structure described in this work could thus become the basis for a set of other techniques to complement the analysis (e.g. network theory, semi-quantitative simulations or formal verifications) (Falegnami et al., 2019; Patriarca et al., 2018; Yang et al., 2017).

Nevertheless, the main contribution of this paper has been the attention it has brought to the importance of the timing aspect during an ER operation. The proposed approach, using Time as a layer of analysis, allows further exploring the role of multi-functional resources in the various layer, as a buffer capacity due to shared knowledge promptly. On these bases, we believe that the FRAM remains a promising approach to model a large set of WAD varieties, exploring "what, how and when" of an emergency response room in action, as well as many other socio-technical systems; in summary, it supports dealing with the chimeric representations of time in socio-technical processes.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author, Riana Steen, upon reasonable request.

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ENDNOTES

[1] Central Control Room (CCR).
[2] Emergency ShutDown System (ESD).
[3] Emergency Shutdown Valve (ESV).

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