FACULTY OF SCIENCE AND TECHNOLOGY

MASTER THESIS

Study programme / specialisation:

Risk Analysis

The spring semester, 2022

Open / ~~Confidential~~

Author: Annette Fritzke Andresen

Annette Andresen

(signature author)

Course coordinator: Eirik Bjorheim Abrahamsen

Supervisor(s): Morten Sommer

Thesis title: Avoiding that accidents turn into disaster: Barrier management and emergency preparedness in the oil and gas industry - on the importance of having a good link between the facility-specific risk picture and the set-up of emergency preparedness, including training and exercise.

Credits (ECTS): 30

Keywords:

Offshore, emergency preparedness, barrier management, major accident hazards, facility-specific competence

Pages: 73

+ appendix: 74

Stavanger, 15.06/2022
date/year

Barrier management and emergency preparedness in the oil and gas industry - on the importance of having a good link between the facility-specific risk picture and the set-up of emergency preparedness, including training and exercise.

Avoiding that accidents turn into disasters

How to ensure that facility-specific competence is present in an emergency preparedness organisation.

Annette Fritzke Andresen

ACKNOWLEDGMENTS

This thesis marks the end of a master’s degree in risk analysis at the University of Stavanger.

I would firstly like to extend a big thank you to all the informants who took their time in an otherwise hectic workday to assist me in this work. This thesis would not have been possible without your expertise and honest answers.

Furthermore, I owe gratitude to my supervisor, Morten Sommer, for excellent help and supervision throughout this thesis. Your feedback, encouragement and prompt replies have been highly appreciated and helpful. Additionally, your calm mind is a blessing for a (at times) stressed student. Thank you for all your time and effort.

Karianne Eidesen needs to be mentioned for her useful thoughts and valuable ideas for this thesis. Special thanks to Anders Karlsen for all your expertise, time, effort and support. Thanks to Reidar Stupe-Delgado for your insightful tips and feedback, you are a brilliant academic.

I’d like to thank my family and friends – you deserve a mountain of gratitude for all the support and encouragement. I would especially like to thank Julie for the moral encouragement and at times shared frustration through our 5 years together at UiS. Our friendship has taken us through sociology and risk analysis, and from Håbafjell to the Canary Islands. You are awesome.

Finally, to my biggest motivation and motivator – thank you.

Annette Fritzke Andresen
Stavanger, 15th of June 2022

ABSTRACT

Facility-specific competence is crucial in emergency preparedness organisations on offshore oil and gas facilities to prevent emerging situations from developing into full-blown disasters. However, the Petroleum Safety Authority (PSA) of Norway has, over a more extended period, raised concerns regarding possible decreasing levels of facility-specific competence amongst personnel. The concerns stem from the development in the industry where critical analyses that should be used to identify and include the specific challenges are moved away from the facilities and operators and are rather conducted by external companies. As such, this study investigates the research problem: *How to ensure that facility-specific competence is present in an emergency preparedness organisation?*

This study approaches the challenge of including facility-specific challenges and measures to handle these in the establishment of emergency preparedness through semi-structured interviews with various companies and the PSA. The interviews uncover that operating and consultant companies often identify facility-specific challenges through the use of qualitative risk analyses and emergency preparedness analyses. Furthermore, the associated roles and competence needed to handle the challenges are identified in the emergency preparedness plans or as part of an organisational barrier element. The interviews also bring forward that the analyses and methodologies used in the industry today, in many cases, are too generic and technical to identify the necessary information needed in the mapping of necessary facility-specific competence.

Building on the theory of emergency preparedness and answers from the interviews, it becomes evident that the analyses and methodologies used in the industry today need to be properly adapted to each facility in order to secure a red line between the generic analyses and the specific conditions at each facility. It is further suggested and emphasised to increase the focus on ‘de-academising’ the information in the QRA, include relevant personnel in the establishment of the emergency preparedness analyses and plans, establish clear and specific competence requirements linked to the various roles, and map the availability of personnel with necessary competence to better secure that personnel with facility-specific competence is present in an emergency preparedness situation.

TABLE OF CONTENT

Figures and Tables

ABBREVIATIONS

ALARP - As Low As Reasonably Practicable

CRO – Control Room Operator

DAE - Dimensioning Accidental Event

DAL – Dimensioning Accidental Load

DSHA - Defined Situations of Hazards and Accidents

ETA - Event Tree Analysis

FTA - Fault Tree Analysis

MAH - Major Accident Hazards

NCS – Norwegian Continental Shelf

OIM – Offshore Installation Manager

PSA - Petroleum Safety Authority Norway

QRA - Quantitative Risk Assessment

RAC – Risk Acceptance Criteria

TRA – Total Risk Analysis

1. INTRODUCTION

Knowing what to do and how to do it is crucial on offshore oil and gas facilities to prevent emerging situations from developing into full-blown disasters. In this context, knowledge surrounding the facility's designs and the relevant equipment for handling an emergency preparedness situation (called facility-specific competence[1]) is essential in reducing the risk of major accident hazards (MAH) in the industry (PSA, 2006). However, the Petroleum Safety Authority of Norway (PSA) has raised concerns regarding possible decreasing levels of facility-specific competence amongst personnel on offshore facilities (PSA, 2006, 2022). Several audit reports from the PSA contain nonconformities regarding facility-specific conditions, where several of the deviations are directly linked to competence, the set-up of emergency preparedness, and training and exercise (PSA, n.d. a). This implies that important information about facility-specific conditions and challenges may be lacking in fundamental analyses and plans that lay the foundation for emergency preparedness on some of the facilities on the Norwegian Continental Shelf (NCS). It may also mean that some operators struggle to implement the requirements given by the PSA in their regulations.

This study aims to shed light on the worries raised by the PSA regarding facility-specific competence and investigate how the industry tackles the challenge. These insights are also of wider concern, as facility-specific competence is widely considered an essential component of emergency preparedness across sectors and national contexts.

1.1. Research Problem

As the offshore industry historically has had a solid link to the risk field, a vast number of studies and articles are aimed at various challenges. Through databases of peer-reviewed articles[2] it becomes evident that overall few articles tackle the topic of facility-specific competence. Jennings (2020; 2019; 2017) shed light on the role and responsibility of the Control Room Operator (CRO) and Offshore Installation Manager (OIM). However, these studies are mainly aimed at competence assessments and are focused on the UK. Others focus on the use of virtual environments (Norazahar et al., 2018), design of the installation and control systems (Woodcock & Toy, 2011) and the use of indicators for major accident risks (Vinnem, 2010) in the work of situational awareness and human response on offshore facilities. No systematic studies were found where the facility-specific challenges, and competence and knowledge regarding these, have been linked to the emergency preparedness organisation on offshore facilities. Hence, there seems to be an absence of research pertaining to the connection between current procedures and plans for

---

[1] The Norwegian term ***innretningsspesifikk*** have two translations in English. The most common translation used in already existing literature is *installation-specific.* However, the translation used by the PSA is *facility-specific* and is thus the term that is used in this study.

[2] The researcher has used the Scopus and ScienceDirect databases. Relevant search words included in the search have been *installation-specific and facility-specific + competence, offshore, emergency preparedness, barriers.*

emergency preparedness and the PSAs increased focus on the importance of facility-specific competence. In an attempt to address this gap, this study investigates the research problem:

How to ensure that facility-specific competence is present in an emergency preparedness organisation?

1.2. Delimitations

As emergency preparedness in the offshore oil and gas industry is a highly debated topic, with literature that crosses into several disciplines, it has been necessary to draw certain delimitations to narrow down the focus areas of the study. The scope of this study is, first and foremost, to bring focus to the concerns that the PSA addresses regarding facility-specific competence on offshore facilities. Thus, it has been chosen to focus on the knowledge amongst personnel and how operators ensure that the personnel are aware of various facility-specific solutions in an emergency preparedness organisation. Therefore, attention is brought to situations where human action is needed to prevent or mitigate the consequences of a potential MAH. Technical systems that function without the interference of personnel are therefore not included in this study.

Additionally, as the foundation of the study builds on concerns raised by the PSA, and the PSA is a Norwegian governmental supervisory authority, the researcher has chosen to focus on operators and companies linked to the NCS. The study is therefore geographically delimited to Norway.

Furthermore, offshore facilities are complex areas characterised by high-risk work (Skogdalen, 2011). Consequently, accidents of different scales can occur. An overview of previous accidents shows that several accidents which have led to severe injuries or fatalities fall outside the definition of MAH. Nevertheless, the researcher has chosen to focus on MAH as these are incidents with potentially very high consequences. Additionally, the prevention of major accidents also lays the foundation for how various plans and procedures for emergency preparedness, and training and exercise, are prepared.

1.3. Structure

Going forward, section 2 describes the background for the study and gives a brief introduction to the PSA regulations and relevant standards used in the industry. Chapter 3 presents a review of the theoretical contribution used in the study and a presentation of additional research questions. This is followed by a description of the research design, choice of methodology, and data collection in section 4. This section also discusses the validity, reliability and methodological weaknesses and strengths of the study. Section 5 presents the collected data from the interviews and are further discussed against the theoretical backdrop in section 6. Finally, section 7 presents the study's conclusions based on the discussion in section 6, followed by proposals for further research.

2. BACKGROUND

A good understanding of MAH is vital in maintaining safe operations in the offshore petroleum industry. How MAH are managed can help prevent major incidents and ultimately save lives (Step Change in Safety, n.d.). MAH is a source of danger that has the potential to cause a major incident, whether that involves multiple fatalities and/or significant damage to plants, equipment, or the environment (PSA, 2022, p. 11). Therefore, effective risk management of MAH should be included in every aspect of the industry, from design and construction to operations and maintenance.

MAH can best be described as a high consequence low frequency event (Ditchburn & David, 2006, p. 3), and include events such as fires, explosions, the accidental release of dangerous substances or any other event with the potential to cause multiple deaths or serious injuries (Step Change in Safety, n.d.). An analysis of historical data on the overall development in risk levels on the NCS shows that there, in general, have been few MAH in the past two decades (PSA, 2022). However, several incidents have had the potential to develop into a MAH if they had not been handled and averted (PSA, 2022, p. 72). The fact that the incidents have not developed into a MAH indicates that the various barriers that are put in place have functioned as they should (Aven et al., 2004). Barriers help prevent major accidents from happening or mitigate the potential consequences if one were to occur. The barriers fall into three categories: *technical*, *operational*, and *organisational*. The first relates to technical equipment or systems whereas the two latter relates to the roles and actions of relevant personnel.

Previous major accidents have led to significant changes in various barriers, procedures, and technologies (Skogdalen & Vinnem, 2012, p. 48). Additionally, a focus to reduce costs, optimise the performance of industrial assets and improve the environmental footprint of the production has led the offshore petroleum industry to witness significant development in technology, and production methods and facility designs are vastly different today than what it was in the late 1960s (Norwegian Petroleum, 2021). Simultaneously, new possibilities and threats have risen with the introduction of new technology, which has resulted in several different facility-specific solutions and has led to more comprehensive competence requirements regarding the handling and realisation of various barriers (Tveiten et al., 2012; PSA, 2006).

Investigations into previous major offshore accidents have revealed that human error and lack of competence have been judged to be the root cause of many of them (Skogdalen & Vinnem, 2012, p. 48; Jennings, 2019, p. 1). Always having personnel present with the correct knowledge regarding the different facility-specific solutions and challenges linked to these is, therefore, crucial in the ever-ongoing work of managing the risk of MAH (PSA, 2006). However, the PSA emphasise that there are reasons to question if the level of facility-specific competence is good enough or if there is room for concern that this type of competence is gradually decreasing amongst personnel. A review of the reports on trends in the risk level on the NCS issued by the PSA and literature covering current procedures on offshore facilities makes it possible to highlight three main areas that could be the basis for this concern:

1. The work of identifying and assessing MAH is rarely done by the facility operators. A valuable and well-used tool to assess MAH is Quantitative Risk Analysis (QRA). However, QRAs are highly time-consuming to conduct. Consequently, Jones et al. (2017) states that the QRA's are often carried out by external companies specialising within the field. This means that the operators who conduct the QRA have specialised competence about how systems work and how a hazard or accident in one area of one system on the facility can affect other systems. Therefore, it is questionable if the necessary information from the QRA to ensure facility-specific competence is transferred from the operator conducting the analysis to the personnel working on the facility (PSA, 2006).
2. More and more of the equipment maintenance is carried out by construction companies. This means that there is a possibility that the necessary facility-specific competence is lacking among the employees working day-to-day on the facility (PSA, 2006, 2022).
3. In recent years, necessary training and exercise have focused on general competence amongst the personnel (Milch & Laumann, 2019, p. 90). This is because new organisational methods and technical changes put emphasis on general and standardised competence resulting in an increased focus on "generalists" rather than specialists, despite that a low degree of technical and procedural standardisation requires facility-specific competence (PSA, 2006)

The challenge now facing the industry is that even though the focus on facility-specific competence has increased, there is little overall guidance on procedures for ensuring that the right competence is present in specific situations. Thus, it is largely up to each company to ensure facility-specific competence. This is an essential characteristic of the Norwegian petroleum regulatory framework, namely that it works as a functional framework. In a functional framework, the requirements describe what is to be achieved but not which specific methods should be used to achieve the required level of safety. The Norwegian system is built on a mindset that the companies, not the government, are responsible for safe operations. Therefore, the regulations issued by the PSA are an essential pillar for how activities in the offshore industry are carried out. However, as the regulations lack detailed guidance, the industry has over time developed different standards to help provide various companies with more detailed descriptions of how to achieve the requirements set by the PSA. Since the PSA regulations and standards contain essential information on how the industry carries out plans and procedures for safe operations, the two following sections will give a brief explanation of the purpose of the regulations and standards, as they both will be mentioned throughout the study.

2.1. The PSA Regulations

For decades, the petroleum industry has been characterised by high standards of safety requirements, especially on offshore facilities, due to the high-risk nature of the production. The primary purpose of these requirements, issued by the PSA, is to secure work-related safety for the employees and minimise or prevent hazardous conditions that can cause injury to personnel, the environment, and assets

(Skogdalen, 2011; Røyksund & Engen, 2020). The PSA is a government supervisory and administrative agency with regulatory areas of responsibilities that covers safety, the working environment, emergency preparedness and security in the petroleum sector (PSA, n.d. a). The PSA refers to itself as both a "watchdog" and "guide dog" for the industry in that it, on one side, supervises that the companies always operate prudently, and on the other side, aims to constantly contribute to managing and reducing risks in the industry through dialogue with the companies (PSA, n.d. a).

Each operating company is responsible for the safety of its facilities. This principle's argument builds on the fact that the detailed knowledge, decision-making authority, and the resources needed to ensure compliance with the regulatory requirements rest with each company (PSA, 2017a). However, the company also has special responsibility for ensuring that the operation takes place in accordance with the regulations. The regulations have been divided into four main frameworks (PSA, 2017a, p. 16):

- *The framework regulations* provide frameworks for the performed activities and include provisions on the scope of regulations, responsible parties, risk reduction principles, etc.
- *The management regulations* where all management requirements for HSE are gathered. Additionally, specified requirements for risk reduction principles, safety barriers, resources and processes, analysis, measurements, etc. are stated.
- *The facility regulations* comprise the design and layout of facilities. They also include information regarding physical barriers, emergency preparedness, safety functions and loads, etc.
- *The activity regulations* help to govern different events. They specify the requirement for various aspects such as condition and monitoring, natural environment, maritime operations, and maintenance, etc.

In order to avoid misunderstandings about what is required to comply with the requirements of the regulations, the PSA often refers to recognised industry standards for guidance.

2.2. Standards

To help ensure sufficient safety, value-adding and cost-effectiveness for the developments and operations in the petroleum industry, different standards have been developed. There are, in general, two recognised standards that are being used in the regulations on the Norwegian continental shelf, the *Norwegian Shelf's Competitive Position Standards* (NORSOK), and the *International Organization for Standardization* (ISO). The standards are developed over time and are built on specific expertise within different subjects in the petroleum industry. They aim to serve as a reference in the authorities' regulations by giving detailed descriptions of how procedures should be done (ISO, 2021; Standards Norway, 2021). The standards are also a fundamental part of the PSA regulations. The regulations are generally formulated in functional terms, meaning that they provide documentation of what goals the responsible parties shall fulfil, but they do not give instructions on how to achieve the goals. In managing and mitigating the potential consequences of MAH, the PSA has issued requirements stating that companies should conduct risk analysis and emergency preparedness assessments (PSA, 2017a). The two procedures are vital in mapping which competence is needed and the associated performance requirements on a facility. The regulation states what needs to be included in the analysis and assessment but does not give any further instructions. However, under the Management Regulations, the PSA has stated that the NORSOK standards ought to be used as a tool to fulfil the requirements regarding the assessment of risks and emergency preparedness analysis (Skjerve et al., 2008, p. 9).

The NORSOK Z-013 standard is developed to establish requirements to ensure effective planning and execution of both risk- and emergency preparedness assessments and addresses both technical and operational aspects of safety. Its main elements focus on (NORSOK, 2010):

- the use of risk and emergency preparedness assessment as a basis for decision-making, and general requirements for how these assessments should be planned and carried out regardless of activity and life cycle phase;
- more specific requirements for planning and execution of assessments for various activities and life cycle phases;
- the relation between risk and emergency preparedness assessments and how to integrate the two types of assessments into one general assessment process.

The Z-013 standard is therefore a valuable and well-used tool to establish the risk picture and how to assess potential risk-reducing measures.

3. THEORY

This chapter emphasises some of the theoretical terms and processes relevant in discussing the research problem. It is possible to view the topic of facility-specific competence from several different angles. Due to the formulation of the research problem, the author has chosen to discuss the question through the lens of the emergency preparedness process (subchapter 3.2). However, competence is defined as an important part of organisational barrier elements (Eriksen et al.,2 2021; PSA, 2017b), and facility-specific information needed in identifying the necessary competence is commonly derived from risk analyses (Proactima, 2021; Skogdalen & Vinnem, 2011). Thus, both the terms *barriers* and *quantitative risk analysis* will be introduced in the following subchapter (3.1). This is to provide the reader with a backdrop of theoretical terms that will be repeated throughout the study and provide a foundation for the results and discussion presented in chapters 5 and 6. Additionally, a brief introduction to the risk term will be given as a starting point.

3.1. Key concepts

The following section will give a brief introduction to different key concepts that are seen as relevant in discussing facility-specific competence and emergency preparedness.

3.1.1. Risk and Different Understandings of the Concept

Risk is paramount to our understanding of human agency, and it is hard to pinpoint as it can be applied to different disciplines depending on what we as humans wish to accomplish (Renn, 2008, p. xiii). With the emergence of modernity, the concept of risk has seen several changes both in its meaning and use. Over the centuries, the term has gone from originating as an act of God to being framed as an expression of mathematics, relying upon the probabilities and consequences of mostly unwanted events (Lupton, 2013, pp. 5-8). Despite the development in the understanding of the concept, there exists no agreed definition. The lack of agreement within the risk field has led to a plethora of definitions arising:

- Risk is a measure of the probability and severity of adverse effects (Lowrance, 1976)
- Risk is equal to the triplet (si, pi, ci), where si is the *i*th scenario, pi is the probability of that scenario, and ci is the consequence of the ith scenario, i = 1, 2, ..., N (Kaplan and Garrick, 1981).
- Risk equals the expected loss (Willis, 2007).
- Risk is the combination of the probability of occurrence of harm and the severity of that harm (NORSOK, 2010).

The above definitions are only a selective list of definitions to illustrate the diversity in various understandings of the term. Several articles exist where a more extensive number of definitions are presented (see e.g., Aven, 2010; Aven & Renn, 2009; Aven et al., 2011). Nevertheless, it highlights that a common understanding of the term is that risk is a combination of an event (A), the consequences (C) of this event, and probabilities (P) (Fjaeran & Aven, 2021a, p. 7). This way of understanding risk is often found in traditional approaches to risk assessments. These definitions can further be divided into two categories (Aven & Renn, 2009):

a) Risk is expressed by means of probabilities and expected values
b) Risk is expressed through events/consequences and uncertainties

The previously dominating understandings of the term have in common that probability and the expected consequences are the predominant tools used to measure the overall risk, and they are all to a large degree structured around three fundamental questions presented by Kaplan and Garrick (1981):

1. What can happen/go wrong?
2. How likely is it that the given event will occur?
3. What are the consequences of the event if it occurs?

However, Aven (2020) argues that these perspectives and definitions are too narrow, and thus, using them might lead to difficulties when assessing risks characterised by high uncertainties, potentially high consequences, and conflicting stakeholder values (Fjaeran & Aven, 2019b, p. 675). Earlier definitions do not take into consideration the uncertainties that could be present in each situation or hazard. This is due to the assumptions and suppositions that the assigned probabilities are conditioned on, meaning that the probabilities often are dependent on the background knowledge of the system in mind. Restricting attention to background knowledge and probabilities could potentially camouflage factors that could lead to unforeseen outcomes (Aven, 2010, p. 626). Aven (2020) further states that a clear distinction should be established between the concept of risk (how it is defined) and how risk is measured in reality.

As mentioned above, the traditional way of understanding risk can be presented as R = (A, C, P). However, Aven and Renn (2009) present a definition that gives more room for the potential uncertainties and states that “risk is uncertainty about and severity of the consequences (or outcomes) of an activity with respect to something that human’s value” (p. 6). According to this definition, risk is more formally seen as a two-dimensional combination of an event (A) and the consequences (C) of this event, and the uncertainties (U) associated with the event and the consequences, resulting in risk described as:

$$R = (A, C, U)$$

The risk can then further be described through (C’,Q | K) where C’ stands for some specified consequences of the considered event or activity. C’ describes the potential consequences identified by an assessor at a specific time and can, therefore, differ from the actual consequences, C, in the future. The distinction between C’ and C means that predicting the future is impossible due to uncertainties. Q is a description of the uncertainties linked with C’, which typically is a probability judgement and the assessed strength of knowledge (SoK) supporting this judgement. K represents the overall knowledge that C’ and Q builds on (Aven, 2020, p. 59; Fjaeran & Aven, 2019b, p. 682).

By following Aven's argument, uncertainty is a crucial component of the risk concept as risk to a large degree is about making assumptions about a future event. An uncertainty-based perspective on risk has also been integrated into the offshore industry through regulatory requirements. Risk within the oil and gas industry is mainly focused on hazards or accidents, where the outcomes have the potential to cause harm, injury, damage, or financial loss. There are several factors that are subject to uncertainty in the offshore industry: which event will occur; how often will the event occur; and potential causes and consequences of the event. The PSA (2018), emphasise that the potential impact of associated uncertainties must be taken into consideration when suitable solutions or measures are to be selected.

The risk of MAH, albeit being defined as events with overall low probability and high consequences, garners much attention due to the amount of uncertainty linked to it. The uncertainty comes from the complicated nature of MAH, as they involve a complex risk picture, several chains of events and failure in several safety-critical features (Jonassen & Sjølie, 2016). Thus, major accidents are both challenging to prepare for and hard to predict. Subsequently, it is crucial to find suitable systems that capture the complexity and reduce uncertainty when managing MAH. Aven (2020, p. 169) states that risk management, to a large degree, is about creating the right balance between development and protection, where the goal is to create value and at the same time avoid accidents, injuries, and losses. In order to achieve this balance, additional safety measures related to both technology and operations are implemented in the form of different barriers.

3.1.2. Barriers

A central lesson learned from previous major accidents is that safety barriers need to be implemented in an integrated and consistent way in order to minimize the risk of MAH (Lauridsen et al., 2016). Nevertheless, similar to the concept of risk, there exists no common terminology of the concept of barriers in the literature, nor in practice (Sklet, 2006a, p. 13). It is, however, agreed that the role of a barrier in general is to prevent or limit the consequences of a major accident (Jonassen & Sjølie, 2016), and that they should work as additional protection to already safe and robust solutions (PSA, 2017b).

Safety barriers have been used since the origin of human beings to protect property and individuals from enemies and natural hazards. As the number of human-induced hazards grew as a result of industrialism, new safety barriers were implemented to minimise or prevent accidents caused by these hazards (Sklet, 2006b). The concept of barriers builds on the so-called energy model (Figure 1 below), introduced by Gibson (1961, as cited in Sklet, 2006b, pp. 494-495). The model illustrates that accidents can be prevented by focusing on a potentially dangerous amount of energy, such as pressure, weight, heat, and explosions, and then implementing measures that will separate the energy from vulnerable elements (such as humans, assets, and the environment).

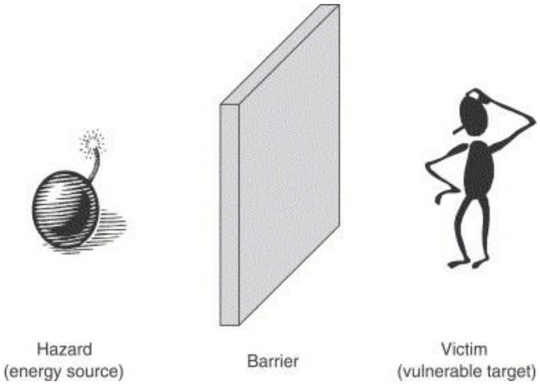

Figure 1 The energy model (Sklet, 2006b)

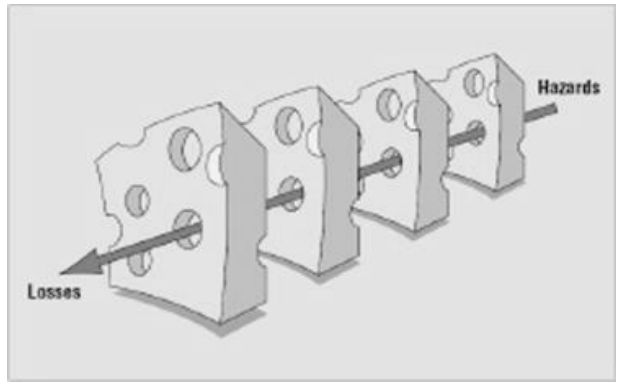

Figure 2 The Swiss Cheese model (Reason, 2016)

An extended perspective on barriers has evolved during the past decades, especially in the offshore industry. The introduction of increasingly complex systems has resulted in the need for more indicators regarding the safety systems (Eriksen et al., 2021, p. 135). Whereas barriers used formerly to defend individuals and property from enemies mostly were of a physical nature, the modern types of barriers may be passive (independent of external activation) or active (where external activation is required), physical, technical or human/operational systems that combine different elements to create a *defence-in-depth* (Njå et al., 2020; Sklet, 2006b). The idea behind defences-in-depth is presented in Reasons' (2016) "Swiss Cheese" model (Figure 2), which illustrates how multiple layers of safety, one behind the other, is securing the barrier by guarding against the possible breakdown of the safety measure in front (Reason, 2016, p. 7).

The various barrier elements that need to be considered to create a defence-in-depth on offshore installations relate to technical, operational, and organisational measures that collectively form a part of the realisation of a barrier function (Lauridsen et al., 2016). The function of a barrier means which specific role the barrier has, such as preventing leaks, preventing ignition, reducing fire loads, and ensuring safe evacuation to mention some (PSA, 2017b). Different barrier elements are needed in the realisation of barrier functions (Eriksen et al., 2021, p. 136):

- *Technical* barrier elements are the system and equipment that need to be included in the realisation of a barrier function. An example of a technical element can be sensors for fire detection.
- *Operational* barrier elements are the specific actions or activities that personnel must implement to realise the barrier function, such as manually activating deluge (sprinkler system) in case of failure of automatic release.
- Finally, *organisational* barrier elements relate to personnel with defined roles or functions, and includes personnel with specific competence. For the example used above, this can be knowledge about where the manual release system is located and when it should be activated.

In other words, it is possible to ask the question, “who does what, and using what equipment when dealing with failures, hazards, and accidents?” (PSA, 2017b). This also shows that the barrier elements are linked together. In several industries, especially the oil and gas industry, it is common to limit safety barriers to measures that are planned to be implemented under the leadership of the emergency preparedness organisation. In this way, there is a distinction between security measures, such as an automatic detection system or a firewall, and measures in an emergency preparedness situation (Aven et al., 2004; Njå et al., 2020). For the purpose of this study, the author has chosen to follow this argument and focus on the operational and organisational barriers as active barrier elements that are activated *after* an event has occurred, when a technical barrier has failed, and thus, their role is to mitigate the potential consequences of the situation. The two elements will often be mentioned together as operators need to identify the operational barrier element to map the necessary competence through organisational barriers.

In order to measure the functionality of a barrier, various performance requirements to ensure the effectiveness are set for the different barrier elements. According to the PSA (2017b), performance requirements are verifiable requirements related to barrier element properties to ensure that the barrier is effective. They can include aspects such as functionality, effectiveness, integrity, reliability, availability, ability to withstand loads, robustness. For organisational barriers performance requirements are often set for i.e., expertise and mobilization time (PSA, 2017b, p. 15). Performance requirements are essential for safe design and for following up safety through barrier management in the operational phase.

Barrier management

Barriers degrade over time, and a safety system may gradually and unnoticeably drift towards a state of high risk if not managed. Barriers must therefore be systematically managed to maintain and improve their performance throughout the system's lifetime (Johansen & Rausand, 2015). Barrier management relates to the continuous process of ensuring that necessary barriers are identified, in place and maintained (PSA, 2017b). The barrier management process can be divided into a design phase, where the barriers are identified and established, and the operational phase, where barriers are maintained and followed up. The design phase focuses on identifying and designing barriers to meet the necessary risk reductions that are seen as relevant to be obtained during operation and in the case of an unwanted event (Eriksen et al., 2021, p. 135). In the operations phase, the focus is on maintaining the barriers to ensure that they function as they should and are available (Hauge & Øien, 2016).

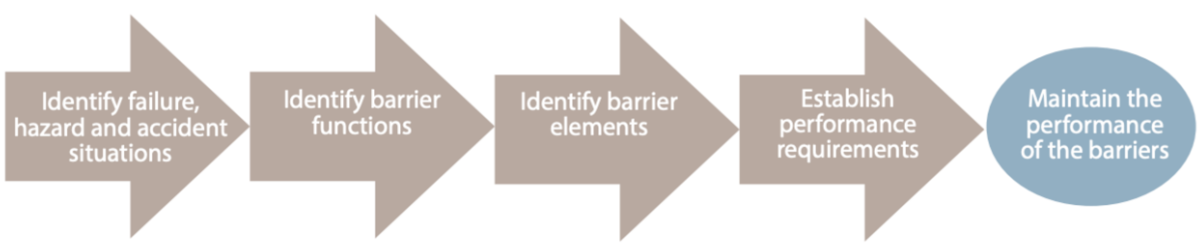

Figure 3 Barrier management process (PSA, 2017b)

Maintaining the barriers is vital, as changes in the performance of a barrier can change the risk picture. Thus, identifying such changes is essential in monitoring safety (Aven et al. 2004). Barrier management includes everything that must be in place of processes, systems and measures. The PSA (2017) emphasises that the personnel working on the facility need to understand the relationship between the facility- and area-specific risk pictures, the need for and the role of the established barriers, and the individual's role in handling risk prudently and well. This can help ensure that the different tools for barrier management and the associated information and results are used appropriately. Furthermore, relevant personnel must understand the barrier's function, associated performance requirements and the importance of monitoring the condition of the barriers. By monitoring the condition of a barrier, it will be possible to ensure that any uncertainty is addressed and that the barrier's properties are maintained and perfected over time. Overall, it is about understanding and defining the potential dangers that arise in a system at any given time and facilitating the best possible management and minimisation of the risk in a controlled manner (Aven et al. 2004).

In order to map the various operational and organisational barrier elements, and to identify the necessary competence, the operators are dependent on information regarding the identified risk relevant for the facility in focus and what is needed to handle the different MAH. This information is mainly structured around the design and the technical systems on the facility and is often identified through the use of risk analyses and emergency preparedness analyses (Hauge & Øien, 2016).

3.1.3. Quantitative Risk Analysis

For the past 40 years, Quantitative Risk Analysis or Quantified Risk Assessment (QRA) has frequently been used as a tool to support risk-related decisions in several industries (Aven, 2020, p. 5). It is a systematic and formal approach used to analyse the likelihood and consequences of potentially hazardous events where the results are expressed quantitatively as risk (DVN, 2021). In theoretical terms, *risk analysis* and *risk assessment* usually have two different interpretations, where risk analysis is included as one of several steps conducted in a risk assessment. Nevertheless, whichever term is used (analysis or assessment), QRAs include an evaluation of the validity and robustness of the quantitative results by identifying risk driving elements and critical assumptions in addition to the analysis (NORSOK, 2010, p. 13-14). This way of assessing risk is also commonly referred to as Total Risk Analysis (TRA), Probabilistic Risk Assessment (PRA), Probabilistic Safety Assessment (PSA) and Concept Safety Evaluation (CSE) (Skogdalen & Vinnem, 2011, p. 469). However, QRA and TRA are more frequently used. The term QRA refers to all the different techniques stated above in this study. Other risk analysis methods exists as well, however

On offshore facilities, the purpose of the QRA is to identify potential MAH that can occur on the specific facility in focus, quantify the risk contribution from each of these, analyse the potential consequences of the MAH, and provide input to the design of necessary safety barriers. Two apparent objectives of the QRA are to (Proactima, 2021):

- Compare calculated risks with the risk acceptance criteria (RAC) set by the operator and applicable Safety Legislations. RAC are often expressed as a maximum tolerable frequency value (probability) of fatalities, of asset damage and of environmental impact. Two examples commonly used in the offshore oil and gas industry are (NORSOK, 2010):
    - The FAR value should be less than 10 for all personnel on the facility, where the FAR value is defined as the expected number of fatalities per 100 million exposed hours.
    - The frequency 1 x 10^{-4} annually for each type of accidental load has been used frequently as the limit of acceptability for the impairment of each main safety function.
- To use the results for defining Dimensioning Accidental Load (DAL), i.e., to describe the accidental loads (e.g., heat load, blast load, mechanical impact load and environmental load) for which the facility has to be designed to achieve an acceptable level of safety. DAL is used to check the adequacy of the supporting structure as well as all safety critical elements.

This means that QRAs are conducted in the design phase of a facility or when major modifications are being done. Additionally, it emphasises that QRAs mainly focuses on technical safety systems and their capabilities (Skogdalen & Vinnem, 2011; Aven et al., 2011). Consequently, the QRA does not include the operational and organisational barriers that must be in place, but it does provide valuable facility-specific information regarding design and various challenges that is used in the identification of these barrier elements later on.

To identify the different events, a QRA must include some analytical elements that are required to identify the applicable hazards and the risk arising from them. Vinnem and Røed (2020) emphasize three different points that may be included in these elements:

- The identification of initiating events
- Cause analysis (including qualitative evaluations of possible causes, and analysis to determine the probability of certain hazardous events)
- Consequence analysis

The Identification of Initiating Events (HAZID)

Identifying initiating events is often referred to as hazard identification [HAZID]. HAZID is a systematic and structured process for the identification and review of different hazards in the early phase of the design of a facility or during planning of activities (Proactima, n.d.). For offshore facilities, the aim of this stage is to gain a broad overview of potential hazards that can lead to accidents - resulting in impairment of personnel (injuries and fatalities), environment (oil spills) and financial assets - followed by the work of screening which hazards are seen as critical (as opposed to non-critical) for further analysis (Vamanu et al., 2016). However, it is crucial that no relevant hazards are left out or overlooked, as hazards not identified at this stage are excluded from further assessments. Therefore, it is also important that the reasons why some hazards are identified as non-critical are well documented (Vinnem & Røed, 2020, p. 5). As a generic practice, a HAZID should address the following phases (NORSOK, 2010, p. 23):

a) an overview of all the potential hazards and causes of accidents
b) the rough identification of the possible consequences of each of the hazards
c) a rough classification into what is seen as critical / non-critical hazards
d) identification of the control measures addressing the specific hazards (e.g., inherent safer design, possible design improvements, etc.)
e) prioritisation of hazards in respect to criticality; identify which of the hazards require further evaluation; establish the level of detail and the type (e.g., qualitative or quantitative) of the assessment.

Identifying different hazards involves having a solid knowledge of the system that is analysed. For instance, for a facility, knowledge about the design and technical systems of that facility is essential in having accurate results at the outcome of this process (Vinnem & Røed, 2020, p. 5). The applicability of the techniques will largely depend on the subject of the assessment (assessment aimed at a facility, a process, hardware/software, etc.). Moreover, evaluating how well the hazards are known will also affect which technique is used. HAZID for existing technologies heavily relies on already established studies and experience, and a simple identification method may, in that case, be sufficient. New technologies, however, will demand a more thorough analysis to confer adequate confidence that the relevant hazards have been identified (Vamanu et al., 2016).

Cause Analysis

If the initiating incident has been addressed and considered to be of interest for further investigation, a cause analysis will be performed where the purpose is to identify which underlying factors that are necessary for the incident to occur. The main logic of a cause analysis, regardless of which method is used, is to come up with a set of events, whose joint occurrence leads to the initiating event (Aven. 2020, p. 110). Additionally, a cause analysis has the objective to assess the probability of initiating events and identify different possibilities for risk-reducing measures. If different causes can be identified, a basis for possible prevention of accidents can be established by either controlling or eliminating the causes (Vinnem & Røed, 2020). There are both qualitative and quantitative methods to establish the various causes.

Qualitative analyses aim to identify combinations of conditions and causes that will result in the occurrence of the initiating event and establish a basis that later can be used for quantitative analysis. Methods that often are used are HAZOP, Fault Tree Analysis (FTA), Failure Mode and Effect Analysis (FMEA), Preliminary Hazard Analysis (PHA) and analysis techniques that focuses on human error, such as Task analysis and Error mode analysis. Due to the increased focus on human error in accidents in recent years, human error analysis has gotten an increasingly important place in cause analysis.

Quantitative analyses aim to establish the probability for the initiating event to occur, where some of the most common methods to do so are FTA, Event Tree Analysis (ETA), Monte Carlo simulation, Synthesis models, and calculation of frequency of initiating events based on historical statistics. The FTA is usually a central tool in QRAs and various other accident investigation methods (Skogdalen & Vinnem, 2012). The strength of the FTA is that it is a method that can be qualitative, quantitative or both, in addition to its ability to break down accidents into different root causes (Sklet, 2004, p. 32). Nevertheless, Vinnem and Røed (2020) emphasise that calculation of the frequency of initiating events based on historical statistics is the most commonly used method in the offshore industry. The frequencies are usually based on analysis of previous accident experiences and adjusted through a modelling of the activity level and special conditions at the relevant facility. It is, however, a method that is quite heavily criticised as its primary focus is to provide a number without giving any information regarding ways in which accidents can be prevented from occurring. Additionally, when applying Avens (2020) perspective on how to define risk, it becomes evident that basing the analysis on historical statistics gives little room for potential uncertainties that can occur in the future. The method should therefore be used with caution (Vinnem & Røed, 2020, p. 7).

Consequence Analysis

For each initiating event, an analysis will be performed to address the possible following consequences (Vinnem & Røed, 2020, p. 7). The assessment of the consequences can be performed by several different mathematical or empirical models, and ranges from detailed modelling (where one of the most commonly used methods is Event Tree Analysis (Skogdalen & Vinnem, 2012)), to coarse judgment assessment from already available data. This means that the consequence analysis may be qualitative, semi-quantitative or quantitative, depending on the context (NORSOK, 2010, p. 24).

The consequence analysis is both a challenging and highly important part of the QRA. The main challenge is the modelling of accident sequences, where different steps of various sequences need to be identified. Gaining an overview of the accident sequences is important because it gives insight into how different technical safety barriers might work or fail. There are usually a number of barriers in place on offshore facilities to contain or mitigate the effects of hazards. However, these barriers might not always be sufficient in severe accident conditions, as there will always be some limitations regarding the design basis (Vinnem & Røed, 2020, p. 7). The consequence analysis is therefore often made up of a series of steps to map out the possible function, or failure of, the barriers involved in the initiating event to describe or define various escalation possibilities. Consequence assessment on offshore facilities mainly addresses events related to loss of containment and the level of impact it might have on people, assets, and the environment. The loss of containment can happen in several ways, and the consequences will thus vary. The type of release, the location, the weather/wind direction, the physical and chemical properties of the substance released, etc., will all impact the potential outcome. There are in general two main areas of interest in this phase (Vamanu et al., 2016, p. 17):

- The release of gas in the atmosphere – which potentially can lead to fires, explosion (due to the formation of explosive vapour cloud) or concentrations exceeding different threshold values (e.g. IDLH, TLV, STEL); the effects of such releases are acute toxicity, thermal effects and explosion (blast and fragment);
- Release of oil which can lead to fires (pool formation) or spreading and/or pollution of the environment.

A final important aspect of the QRA is that it provides valuable information about assumptions, boundaries, and uncertainties linked to the risk model and the risk calculation results. Suppose the QRA identifies potential weaknesses or questions the ability of, e.g., the structure of a physical barrier (e.g., a firewall) to withstand a fire after a certain number of minutes. In that case, this will significantly influence emergency response planning. The findings from the QRA will give important information regarding challenges linked to the emergency preparedness. Nevertheless, while the QRA identifies what can happen and where it can happen, it gives little information on how to handle the identified MAH (Eriksen et al., 2021, p. 16). Consequently, risk analyses need to be combined with emergency preparedness to plan how to respond to a situation.

3.2. Emergency Preparedness

Inadequate preparations, mismanagement or a response strategy not adapted to the context may quickly turn several types of accidents into crises and emergencies (Kruke & Auestad, 2021). Emergency preparedness is a term that reaches across several disciplines and is yet another concept lacking a unison agreement on the definition (Eriksen et al., 2021; Kirschenbaum, 2002). Historically, the concept of preparedness has been a culturally bound phenomenon that has been linked to various social structures and locations. Thus, its meaning and substance are likely to have varied (DeVries, as cited in Kirschenbaum, 2002, p. 6). However, in its general form, emergency preparedness is about being prepared to handle an unwanted situation (Eriksen, 2021, p. 15). Another aspect of the concept that scholars in general agree upon is that emergency preparedness, rather than being an isolated phenomenon that can be observed and measured, should be understood as a continuous, holistic process (Eriksen et al., 2021; Staupe-Delgado & Kruke, 2017; Perry & Lindell, 2003; Gillespie & Streeter, 1987). Kirschenbaum (2002) argues that various definitions has evolved from different angles for how to view preparedness. Most of the definitions available are categorized in terms of attributes of preparedness, i.e., their physical or technological components. Others are focused on scenario planning and psychological processes involved in emergency preparedness. An additional group are definitions that are dominated by organisational concerns. The latter has a clear parallel to the NORSOK Z-013 standard (2010) which defines emergency preparedness as "technical, operational and organisational measures, including necessary equipment that are planned to be used under the management of the emergency organisation in case hazardous or accidental situations occur, in order to protect human and environmental resources and assets" (p. 9). Thus, the organisational aspects of emergency preparedness are the focus area of this study.

Eriksen et al. (2021) argues that the process of working with emergency preparedness is far from a set cook-book recipe where the outcome is a bulletproof emergency preparedness plan (EPP), but rather a continuous cycle that need to be evaluated and updated. Additionally, emergency preparedness stretches across several phases which can be divided into a pre-crisis, acute crisis, and post-crisis phase (Engen et al., 2016; Staupe-Delgado & Kruke, 2017; Kruke & Auestad, 2021). The work of planning the emergency preparedness is done in the pre-crisis phase, where important input stems from conducted risk analyses, such as the QRA. In the oil and gas industry, this work is often done though external consulting companies. Thus, Eriksen et al. (2021, p. 72) stresses the importance of the consultant companies involving personnel with relevant knowledge and competence surrounding facility-specific conditions as they will prvide valuable input to the establishment of various emergency preparedness solutions. The mobilization and realization of the emergency preparedness organisation appear in response to a crisis, while evaluation and necessary improvements are done in the past-crisis phase (Engen et al., 2016). However, as the QRA provides little input regarding necessary equipment, personnel, and competence when faced with a potential MAH, a more systematically and detailed approach in establishing the emergency preparedness is necessary (Eriksen et al., 2021). This is where an emergency preparedness analysis (EPA) can function as a valuable tool to connect the risks identified through the QRA to the dimensioning of the emergency preparedness organisation. An illustration of the various phases and associated “tasks” are illustrated in Figure 4 below.

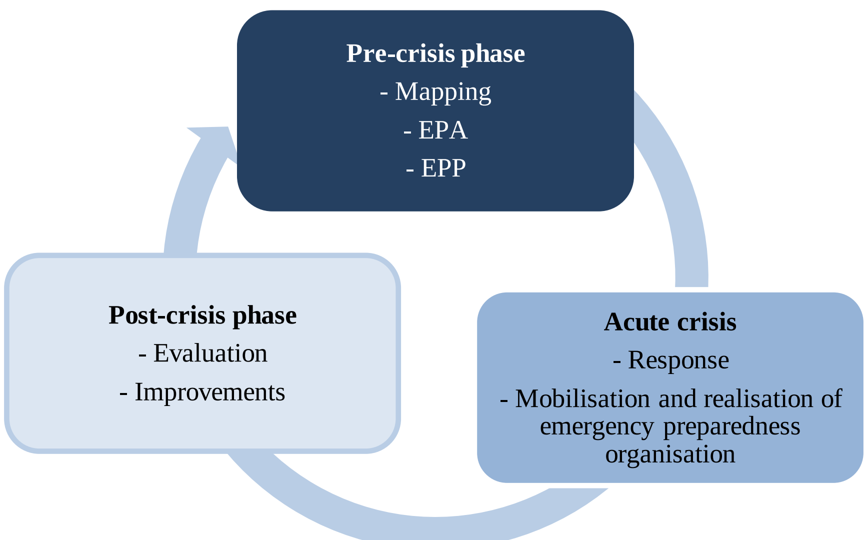

Figure 4 Simplified model of emergency preparedness process (inspired by Eriksen et al., 2021; Engen et al., 2016)

As we can read from Figure 4, the different phases should be seen as a continuous process in order to secure a robust emergency preparedness. Additionally, the link between the various phases also shows how the different elements that is needed in this process are linked together. Following is a short presentation of what should be included in the various phases.

Mapping

In the pre-crisis phase, the operating company should map the various MAH that may occur. This information is as mentioned previously often derived from the QRA or other risk analyses. Additionally, previous experiences and statistics on incidents and measures should also be included (Njå et al, 2020, p. 231). Eriksen et al. (2021) emphasise that, when possible, rapports and analyses from other companies should be included to gain a broader overview of potential hazards. Due to the uncertainty linked to future events, a broad foundation of information in the mapping stage can contribute to valuable insight into possible factors that can lead to a MAH. Furthermore, supporting the

Emergency Preparedness Analysis (EPA)

An emergency preparedness analysis can be defined as; "Systematic procedure for identifying, understanding, and describing emergency preparedness solutions with associated requirements (Eriksen et al., 2021, p. 18). The NORSOK Z-013 standard, working as the guidance document in how to conduct EPA in line with the PSA regulations, builds further on the definition and state that the EPA also should contain certain elements;

> Analysis which includes the establishment of defined situations of hazards and accidents (DSHA), including major dimensioning accidental events (DAE), the establishment of emergency response strategies and performance requirements for emergency preparedness and identification of emergency preparedness measures, including environmental emergency and response measures (NORSOK, 2010, p. 9).

In other words, the purpose of the EPA is first and foremost to establish the DSHA to which the emergency preparedness should be dimensioned for. The EPA should be conducted to determine requirements for the tasks and measures that must be carried out to be able to handle relevant incidents in an effective way. Moreover, it should identify emergency preparedness challenges, performance requirements and emergency measures, solutions and strategies to ensure proper handling of the DSHA (Njå et al., 2020, p. 232). The purpose of an EPA is twofold. First, one must determine what type of MAH the emergency preparedness should be established for and set performance requirements for the response and handling of the emergency preparedness incidents. This is generally done through DSHA, which is described as a "selection of hazardous and accidental events that will be used for the dimensioning of the emergency preparedness for the activity" (NORSOK, 2010, p. 9). Some examples of DSHA linked to MAH that are relevant for offshore facilities are listed in table 1 below.

Table 1 Description of different DSHA related to major accident hazards (PSA, 2020)

DSHA	Description
1	Non-ignited hydrocarbon leaks.
2	Ignited hydrocarbon leaks.
3	Well kicks / loss of well control.
4	Fire / explosion in other areas, flammable liquids, non-hydrocarbon
5	Vessel on collision course (towards the facility)
6	Drifting object (on collision course towards the facility)
7	Collision with field related vessel / facility / anchoring (towards the facility).
8	Structural damage to platform / stability / anchoring / position failure.
9	Leaking from subsea production systems / pipelines / risers / flow lines / loading buoy / loading house.
10	Damage to subsea production equipment / pipeline systems / diving equipment.
11	Evacuation.
12	Helicopter occurrence.

It is worth mentioning that there are also established DSHA for accidents and hazards that fall outside the scope of the QRA (Vinnem & Røed, 2020), such as *man overboard, serious injury to personnel* etc. In general, the DSHAs for other hazards are established as they may potentially result in a challenge for the emergency preparedness organisation and are therefore included in the emergency response planning. This means that hazardous events with a probability lower than $1x10^{-4}$ and hazards associated with large uncertainties also are included. These are, however, not elaborated on in this study.

Secondly, Njå et al. (2020) further states that the EPA is used to identify which resources such as equipment, personnel, competence, etc. are necessary to be able to respond well enough and handle the identified DSHA based on the requirements that has been set.

Emergency Preparedness Plan (EPP)

While the EPA focuses on what is needed to handle a DSHA, the EPP provides guidelines for how the emergency preparedness organisation shall, in an efficient and appropriate manner, handle defined danger and accident incidents. An EPP is documentation that is to be actively used in handling response, and which deals with the identified DSHA for which emergency preparedness is needed (Njå et al, 2020). Here it becomes important to make the EPP as understandable as possible so that it is understood by everyone and to avoid misunderstandings. All companies have a statutory requirement to have a conscious relationship to their operational risk and to have established emergency preparedness (PSA, 2017a). How the EPPs are prepared ca vary from company to company, but their main intension should be to help ensure efficient handling of emergency preparedness and explain how the emergency preparedness should work when an emergency arise. Furthermore, the EPP should (Eriksen et al., 2021, p. 225):

- Have a clear structure
- Be easy to read and understand
- Include guidelines that ensure efficiency
- Provide the emergency preparedness organisation with useful tips
- Highlight the most important information

For the EPP to fulfil the above list of criteria, the plan should not contain too much text as this can make it confusing and difficult to find relevant information. On the other side, even though explanations for how and why can take up a lot of space in a plan, it is still important information that can help secure efficient handling of a situation. Eriksen et al. (2021, p. 226) therefore, argues that personnel should already know the relevant information in various situations and further state that operators can secure knowledge regarding how the emergency preparedness organisation should function and why through training and exercises rather than being stated in the EPP. Another solution is to divide the plan into two different sections, one operational par and one administrative part. The operational part would then give short and clear instructions on how to proceed when faced with a potential MAH, whereas the administrative part would elaborate and provide a more detailed description that can be read and used for training or used as a reference work in various situations if personnel are unsure of decisions (Njå ei al., 2020; Eriksen et al., pp. 225-226).

Response and mobilization of emergency preparedness

In the acute crisis phase, the identified roles, and measures from the EPP are put to their test through the realisation and mobilisation of the emergency preparedness organisation. As MAH occurs so rarely, operators need to test and verify the emergency preparedness organisation through training and exercise. This is to ensure that the EPPs work as intended (Njå et al, 2020). The scenarios to be used for training should be chosen among the DSHAs identified and established in the EPA to ensures that the personnel are trained within relevant scenarios. However, even though the exercises are focused around identified and specified DSHA, the emergency preparedness organisation still need to be flexible. Exercises can ensure a robust emergency preparedness, but events will likely not be identical to the scenarios included in the exercises. The need for adjustments will always be present in the case of a real situation (Eriksen et al., 2020, p. 46). Vinnem and Røed (2020) further argues that once personnel understand their roles and responsibility, they will be able to use the experience from one DSHA to handle other accidental events as well through some degree of improvisation.

Evaluation and improvements

An essential part of the post-crisis phase is to make adjustments by evaluating the emergency preparedness response (Njå et al., 2020, p. 232). Following training and exercises, a debrief is carried out to assess the overall handling, whether the performance requirements are met, that the necessary equipment was available whether there is learning or improvement and suggestions that should be implemented. Consequently, changes are done if the operators see that identified measures in the analysis and plans do not work as intended in operations. However, as the offshore industry in general experiences few MAHs, they also have few situations where emergency preparedness must be mobilised. Thus, the basis of experience is relatively scarce. Therefore, the operators must identify areas of improvements through verifications and audits, both internal and external, and learn from each other, (Eriksen et al., 2020, p. 47).

This model shows that emergency preparedness should be seen as a continuous process that should constantly be improved where possible. It also shows how the EPA connects the technical QRA to establishing emergency preparedness on each facility. This creates a solid overview of how operators should handle unwanted events at each facility, but it also opens for experiences and information to be transferred between different companies.

3.2.1. Including organisational barriers in the emergency preparedness organisation

Who does what with which equipment in failure, hazard and accident situations is an important question to ask when identifying relevant barriers (2017b). Moreover, the purpose of the EPA and EPP is to identify what is needed to handle a DSHA and how the situation should be handled. Thus, the EPA and EPP gives essential input to which operational and organisation barriers that must be in place to protect against unwanted consequences from the identified DSHA. As emphasised by Eriksen et al. (2021), this process should be carefully divided into different terms of content to create a clear overview of the barrier functions, barrier elements and additional performance requirements in the different stages of the emergency preparedness.

The performance requirements give specific instructions on functions and roles in the emergency preparedness organisation, tools, strategies and tactics etc. The importance of performance requirement is also emphasised by the PSA, which states that; "*The most important consideration is not the label attached to the various barrier elements, but the presence of identified and established performance requirements for all the barrier elements regarded as necessary to implement the barrier functions*" (PSA, 2013, p. 23). The performance requirements are furthermore included in a performance standard which specifies the objective, measurable performance and assurance or verification steps required for that barrier (McLeod, 2017).

The performance requirements should be formulated for each DSHA and emphasise the capacity/functionality, availability, and response time for all the various barrier elements. When applied to organisational barriers they will typically give information about who need to be available (x persons with specific competence), when they need to be available (need to be available 24/7/365) and how quickly they should respond to a situation (respond within x minutes) (Vinnem & Røed, 2020, p. 256). Furthermore, once the performance requirements have been established, the barriers condition and compliance with the requirements needs to be verified. For technical barrier elements, in many cases testing, inspection and maintenance will be a good solution for this. However, the challenge arises when trying to verify the performance of operational and organisational barriers, as other systems and processes are required. For verification of the performance of operational and organisational barrier elements, examples of verification activities might be tabletop simulations and various training and exercises for the emergency response organisation (PSA, 2017b).

3.2.2. The role of competence as a barrier in emergency preparedness

By turning the focus to the response in the acute phase, the involvement and competence of various personnel will to a large degree influence the overall quality of the response (Kruke & Auestad, 2021, p. 4). Competence is a concept that has several definitions. Shippmann et al. (2000) conclude that the variations in understandings and definitions are a consequence of the different domains in which the term is used. On offshore installations, in situations that have the potential to develop into a MAH, personnel on offshore facilities must act quickly and correctly while faced with both physical and psychological challenges that involves knowledge, skills and attitudes that rarely are needed in day-to-day operations (Eriksen e al., 2021, p. 126). It is thus agreed that the aforementioned qualities are essential components of competence in the offshore industry (Jennings, 2016). As emergency preparedness to a large degree is about ensuring that personnel perform the correct actions at the right time, their level of competence will be a prerequisite for successful emergency preparedness. Thus, much attention should be paid to the area of competence (Eriksen et al., 2021, p. 125). Furthermore, competence also makes up a significant part of organisational barrier elements, as these are elements covered by personnel with specific competence to carry out specific tasks in an emergency preparedness situation (PSA, 2017b). Eriksen et al. (2021) draws a distinction between competence that can be documented by formal documents such as diplomas, exams, or certifications, and competence in the form of knowledge and skills that a person has acquired through education, work, organisational work, or other activities. Both types of competence are usually included in the emergency preparedness planning.

When focused on active barriers, knowledge of the design of the facility and where the necessary equipment is located is vital. As the emergency preparedness organisation consist of personnel with defined roles, additional requirements for competence should be included to ensure that the personnel posit the necessary knowledge and skills required to ensure the role is carried out in a prudent manner. This, consequently, has a direct influence on the functionality of various barrier functions. To work of identifying what need to be done, with which equipment, will quickly loosie its function if the personnel are unaware of how to do it. Hence, a mapping of the competence needed in the various stages of emergency preparedness in vital in creating a robust emergency preparedness organisation.

Once the required competence related to the performance requirements has been mapped for the different DSHA, the competence requirements can be compared with the various roles, often done though a GAP-analysis. In this way, we get an overview of what competence the people who are to have the various roles in the emergency preparedness organisation must have and comparing it to the competence already present amongst personnel (Eriksen et al. 2021).

The result from the GAP-analysis further provides valuable input to what needs to be included in training and exercises to cover the competence requirements established through the EPA and EPP. Scenarios to be used for training and exercise should be chosen among the DSHAs addressed in the EPA. This ensures that representative scenarios are being exercised (Vinnem & Røed, 2020, p. 258).

3.3. Theoretical Summary

The purpose of the previous sections has been to provide a theoretical foundation of the methods and procedures that are used in the offshore petroleum industry to map which operational and organisational barriers that are needed in an emergency organisation, and how these are included in the establishment of the emergency preparedness organisation. The latter part of the section has focused on how relevant competence as a barrier are identified and included. The section has focused on giving the reader a brief introduction to the concept of *barriers, QRA* and *emergency preparedness*. The aim has been to create a red line between the different procedures and analyses and to establish how operational and organisational barriers are included as a part of the emergency preparedness organisation. A figurative summary is presented below in Figure 5.

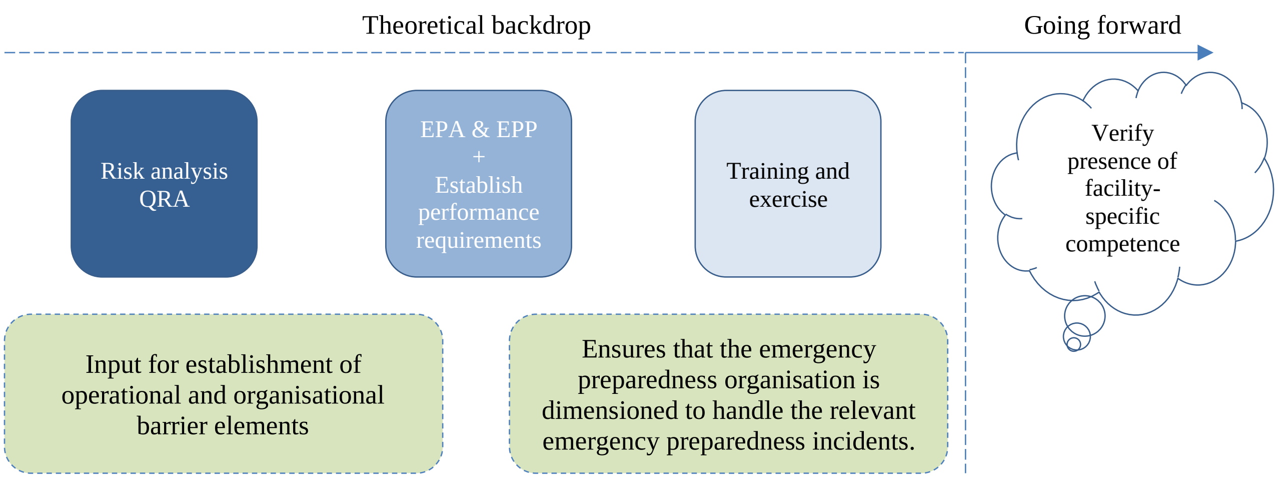

Figure 5 Theoretical summary

The figure presents the different elements that the author has chosen to focus on in answering the research problem; *How to ensure that facility-specific competence is precent in an emergency preparedness organisation*. The various risks on offshore facilities are commonly assessed through different types of risk assessments. This study has focused on the QRA as it is a common method used in the industry. The QRA provides valuable information regarding the design and possible MAH related technical systems on the facility, and thus, lays much of the foundation for the establishment of emergency preparedness. The EPA and EPP are then established to map how the various MAH presented as different DSHA should be handled and includes the identification of different operational and organisational barriers. This section also includes the establishment of performance requirements necessary for the emergency preparedness organisation to function as it in relation to the identified barrier elements should and provides a solid fundament to identify the necessary competence. Finally, the most common way secure relevant competence and to verify the performance of organisational barrier elements is through training and exercise.

Based on the theoretical backdrop, the author has chosen to formulate a set of additional research questions that will create a fundament to build up under the research problem:

- *R1: How do the operators ensure that the right barriers (organisational) have been identified?*
- *R2: How do the operators secure that the identified barriers and associated roles and actions are understood and performed by personnel?*

Question R1 and R2 aims to uncover how the industry uses the theory presented when mapping the various barriers, and consequently, how the personnel are known with the specific roles and actions that needs to be carried out in an emergency preparedness situation. However, the theory does not really include much focus on facility-specific challenges, and specific measures to handle these. Thus, two additional questions have been formulated to study how the current theory, analyses and methods works in practise when linked to facility-specific conditions:

- *R3: To what extent do current analyses and methodologies provide sufficient information about facility-specific challenges?*
- *R4: What adjustments in the current methodology can be implemented to increase the focus on facility-specific competence?*

Going forward, the author will attempt to answer these questions by combining the results from the collection of empirical data with the theory presented above.

4. METHODOLOGY

Before embarking on the data analysis and discussion of the study the author wishes to establish the method used to gather the data needed to answer the research problem. A decision to perform qualitative research was made based on the nature/formulation of the research problem, and thus, led the author to perform interviews with ten informants. The following sections will present the different choices that were made throughout the process. It will include the theoretical backdrop of the chosen method, why the specific participants were chosen, preparation of the interview guide, and how the gathered data was processed.

4.1. Research Strategy

In order to gain an overview of how to best move from the theoretical level over to the empirical part of the study, a research design was prepared before the project started. According to Blaikie (2010), a research design is a working document that contains all decisions that must be made before the data collection is carried out. Additionally, it ensures evaluation and justification of the choices made in reaching these decisions.

The methodology for this study follows the logic of an inductive research strategy. Inductive principles are based on trying to approach and understand a reality that is unknown by developing concepts/theories, and/or models on the phenomenon and creating a holistic understanding of the phenomenon that is being observed (Halvorsen, 2008, p. 128). In other words, the inductive research strategy aims to make generalisations about a phenomenon based on observations and comparisons of the collected data (Danermark et al., 2002). The use of an inductive approach is commonly seen in several types of qualitative data analyses, where the following are some of the purposes of the strategy (Thomas, 2006, p. 238):

1. to condense extensive and varied raw text data into a brief, summary format;
2. to establish clear links between the research objectives and the summary findings derived from the raw data and to ensure that these links are both transparent (able to be demonstrated to others) and defensible (justifiable given the objectives of the research), and;
3. to develop a model or theory about the underlying structure of experiences or processes that are evident in the text data.

The other strategy often used in research is the abductive research strategy. Abductive principles are based on trying to explain a phenomenon through conceptual frameworks by taking an observable phenomenon and placing it in general structures or universal context by applying theoretical knowledge to it (Danermark et al., 2002). This research strategy is ideally suited to answer “why” questions. However, as the research problem in this study is built on a “how” question, an inductive research strategy seemed most relevant as the author aims to tackle a phenomenon that to some degree is unknow. In addition, as mentioned earlier, this study aims to unravel a challenge that seems to be lacking in previous research, and the collection of data will therefore contribute to creating a new understanding of how facility-specific challenges and measures to handle these are identified and included in the emergency preparedness of various operating companies on the NCS.

It is important to emphasise that inductive logic alone is not enough to provide certainty or finally conclude something about the nature of a given phenomenon. Nevertheless, it can provide some insight and give room for plausible conclusions to be drawn. This means that consistent findings through inductive research strategy can support a generalisation, but on its own, it can never prove it to be true. Thus, using the strategy means that the research must always be considered as being subject to revisions and critique, and further research within the same subject area may yield different findings (Blaikie, 2010).

4.2. Research Method

Halvorsen (2008) draws a distinction between intensive and extensive research schemes. Intensive research explores the chosen phenomenon in-depth with relatively few units, while the extensive research is more generalising by focusing on fewer variables whilst including a larger number of units. The most common methods of conducting research are qualitative and quantitative methods. Whilst quantitative research provides a description of reality based on numbers, tables and large units, qualitative data aims to provide a description of reality based on a few units and textual descriptions. Halvorsen (2008) further points to a difference between the two methods where quantitative methods give the author *measurable data*, whereas qualitative methods provide information regarding the non-quantifiable characteristics of the research units. Qualitative methods can further be defined as forms of data collection that do not have statistical generalisation as their purpose, but which are to provide depth, nuances and/or saturation of variation in the phenomenon being investigated (Iversen, 2011, p. 179). In order to answer the research problem, the author is dependent on relevant background knowledge related to the establishment of emergency preparedness, the identification of barriers, and thorough descriptions of the procedures and plans used in the industry. Based on the definitions of the two research methods it becomes evident that a quantitative approach would struggle to capture the depth of knowledge needed. The research method chosen for this study therefore builds on a qualitative research method.

It is worth mentioning that the author considered using a triangulation method of research. This type of research combines various methods to provide a more robust resilience to the results obtained. Moreover, it improves the theoretical and epistemic validity, and reliability of the research gathered (Golafshani, 2003, p. 603). The author has gained access to several documents, plans and procedures that are used in various companies. These documents could have created a solid foundation for document analysis. However, the documents are developed and specified in each company and are therefore confidential. They have contributed valuable insight and a deeper understanding of the topic being researched but using them as a part of the study is not possible due to signed confidentiality agreements. Triangulation through document analysis would consequently be challenging in this study.

4.2.1. Qualitative Interviews

The author decided to perform qualitative interviews as this method is well-used to uncover mechanisms, processes and practices within organisations and structures that are not necessarily on paper. The aim of qualitative research interviews is to produce knowledge and insight through the interaction between the interviewer and the interviewee (Kvale & Brinkmann, 2015, p. 99). Qualitative interviews, also called conversational interviews, resembles an everyday conversation, but the purpose of the professional interview is first and foremost to collect data (Kvernmo, 2005). Additionally, they are often characterized by open-ended questions, meaning that the question asked cannot be answered with a simple yes/no but require the respondent to elaborate on their points (Andersen, 2006). This also gives room for the informants to steer the conversation and gives room and flexibility to ask follow-up questions based on the informants' answers for further elaboration and clarification. The background knowledge of the author is mainly based on theory linked to the areas of risk, emergency preparedness and barrier management, in addition to relevant information gathered for this study. Thus, giving the informants a chance to elaborate on the different questions would also provide the author with valuable information from people with years of experience within the various fields.

The informants that participate in qualitative interviews are normally resourceful individuals who can shed light on different procedures/phenomena and practices within an organisation or in various situations. Andersen (2006, p. 281) distinguishes between two types of open and conversational-based interviews. One type focuses on the personal experiences, opinions, and feelings of the interviewee, while the other type of interviews attempts to extract knowledge about cases, situations, relations, and contexts that are not generally available. The latter being the aim of the interviews conducted in this study. The chosen informants possess knowledge, insights and experiences about processes, practices and procedures that are examined in section 3. The informants act as gatekeepers to valuable information and insight and their subjective opinions and experiences often become the focus of the interviews (Andersen, 2006, p. 282). The objective with the interviews was to do a deep dive into the current plans and processes for handling potential MAH in the offshore oil and gas industry to uncover how it ensures that the facility specific competence is present in an emergency organisation, and potentially highlight some strengths and weaknesses with today's procedures. Data collected from the interviews will help answer the central questions in this study. The theoretical review in section 3 provides an important foundation, but existing theory alone is not sufficient to answer the questions asked in the study. Information regarding how the theory actually is used in practice is vital in providing different nuances and understandings of the research problem. The open and conversational-based interview was therefore viewed as the best approach to obtaining this type of information.

4.2.2. Planning and Conducting the Interviews

An interview guide outlining the scope and the purpose of the research was created as early preparations for the interviews. To ensure that the relevant topics were being covered in the interviews, a set of predetermined questions was written down in advance and included in the interview guide (Attachment 8.1). The questions were formulated so that they would merge the various parts of the theory presented in section 3 with the increased focus on facility-specific challenges and competence. Moreover, the interview guide included questions that would require the informants to elaborate on the already established methods and processes to give valuable information that could help answer the additional research questions asked in the study. The author then emailed the interview guide to the informants before the interviews were conducted. This gave each participant some time to prepare and gather relevant information that they might need to answer the different questions. The informants consisted of people working within various companies with different areas of expertise; thus, the interview questions were adjusted to cover areas relevant to each informant. However, a few general and broader questions were also included in each interview to gain insight into what the informants view as possibilities and challenges with the current procedures and analyses. Moreover, this also created a fundament for comparing several answers.

Due to practical reasons related to the ongoing Covid-19 situation, and due to some informants being located in other parts of Norway, most the interviews were conducted via Teams in the period between April – May 2022 (one interview was conducted physically in person). This has not proved to affect the answers received, and all participants were more than willing to participate. Before beginning each interview session, the informants were asked if they would agree to be recorded via Nettskjema, a self-service solution for secure data collection. All ten agreed and were more than willing to oblige. As stated in the information letter sent out in advance, it was mentioned again that anonymity and confidentiality were promised, as it provided the participants with a 'blanket' of protection and ensured that their identity and professional role remained unaffected by any potentially decisive answers.

All the interviews were recorded via Nettskjema, and then manually transcribed after the interviews were finished. A copy of the transcribed interview was sent to the informant who had provided the answers to ensure that the correct information had been noted and gave the informants a chance to give feedback on the conversation and request minor editing where needed.

4.2.3. Informants

A carefully selected group of relevant companies was chosen so that the different areas of expertise related to the theory chapter would be represented in hopes of providing a 'specialized' focus group. The companies and informants were all selected due to their corresponding expertise, experience and knowledge of emergency preparedness and barrier management in Norway. To ensure that the right informants were included, the interview questions were forwarded to each company to evaluate which of their employees would be most relevant for the author to interview. The different informants consisted of four informants from four different operating companies, two informants from one company that work as suppliers of security studies for the operating companies, and four informants from the PSA. An overview of the informants is seen in Table 2 below.

Table 2 List of informants

Type of company	Number of companies	Number of informants		Area of expertise
Operating company on the NCS	4	4	P1	Barrier management & emergency preparedness
			P2	Barrier management & emergency preparedness
			P3	Barrier management & emergency preparedness
			P4	Emergency preparedness
Suppliers of security studies	1	2	P5	Barrier management
			P6	Emergency preparedness
Supervisory authority (PSA)		4	P7	Barrier management & emergency preparedness
			P8	Emergency preparedness
			P9	Barrier management
			P10	Emergency preparedness

4.3. Analysis Process

Qualitative data are available in the form of unstructured information, and there are no standardised techniques for categorising the data collected (Ryen, as cited in Halvorsen, 2008, p. 210). For this study, the author chose to use thematic analysis to identify and analyse patterns and themes in the collected data (Braun & Clarke, 2006, p. 79). After the interviews had been conducted, the author read through the transcribed interviews several times to categorise the collected information in a thread of common codes and themes pertaining to each of the questions and answers provided by the various participants. By using multiple codes, the author could categorise the information obtained from the interviews and thus, compare the different answers. A challenge with coding is that the author might look for and focus on codes and themes that might not actually be there. The potential for the author to influence the results through coding is rooted in the subjective nature of qualitative research (St. Pierre & Jackson, 2014, p. 716). Therefore, it was important that the codes created built on the questions asked in the interview and highlighted relevant information that would be valuable in answering the research problem. The information coded was always seen in relation to the rest of the paragraph to avoid data being taken out of context.

4.4. Validity and Reliability

In any research project, efforts should always be made to minimize problems related to validity and reliability. A plethora of definitions on how to assess this exists, dependent on the type of methodology chosen (Golafshani, 2003). In general, it means that the author should be critical to the data collected. Jacobsen (2005) highlight three questions that should be asked:

- Did we get the information we needed (internal validity)?

- Can we transfer the findings to other contexts (external validity)?
- Can we trust the data we have collected (reliability)?

These questions and the traditional criteria for validity and reliability find their roots in positivist research logic, such as quantitative research, where the results are independent of the relationships between researcher and informant. From a constructivist perspective, or through qualitative research, data is seen as socially constructed through the interaction between researcher and informant (Golafshani, 2003). Nevertheless, Patton (2002) argues that validity and reliability are two factors that any qualitative researcher should be concerned about while designing the study, analysing results, and judging the quality of the study. However, for the novice researcher, demonstrating clear validity and reliability when undertaking qualitative research is challenging because there is no accepted consensus about the standards by which such research should be judged (Noble & Smith, 2015). Still, the following sections will attempt to bring forward some aspects of the chosen methodology that can be discussed in terms of validity and reliability.

4.4.1. Internal Validity

Internal validity within qualitative research is often associated with terms such as quality, rigor and trustworthiness (Golafshani, 2003, p. 602; Halvorsen, 2008). The internal validity of the findings for this study relates to the selection of interview objects and the focus of the interviews. Based on the nature of the research topic and the theoretical backdrop, the interview questions had to be angled toward the procedures and analyses for emergency preparedness and barrier management carried out today. Different actors usually carry out the theoretical processes presented in section 3, meaning that several companies needed to be included in the data collection. Moreover, each informant in the interviews needed to have the right competence to familiarize themselves with the various questions and to be able to elaborate on the topic in focus. Several companies offer the same services; however, not all are represented in this study (primarily to limit the number of informants). Choosing one company over another could potentially weaken the validity as another company may have another level of competence. Nevertheless, there exists regulations and requirements for how the various analyses are to be carried out and what the plans should contain. Thus, they often cover many of the same points even though they are conducted by different companies within the same field. The requirements and regulations strengthen the validity by adding confidence that the chosen companies and informants have the necessary background knowledge and so, that the information should be trusted. Additionally, the interview questions are not directly aimed at the company they work for but rather the procedures themselves, meaning that there is little chance that informants would withhold information based on concerns related to weakening their own/the company's position.

Finally, as the interviews were recorded and transcribed, it provided the author with a greater opportunity to focus on the informants and ask follow-up questions where needed. Transcription also made it possible to quote the informants and reduce the likelihood of misunderstandings, which in turn helps strengthen the validity of the data collected.

4.4.2. External Validity

External validity is about the extent to which the results can be transferred to other samples and situations - the extent to which they are generalizable. The ability to generalize findings is one of the most common tests of validity when conducting quantitative research.

The chosen topic for this study is relatively narrow as it focuses on facility-specific competence and the current methods used in the offshore oil and gas industry. Generalizing the findings to other situations might be challenging based on this. It is also important to emphasize that the goal of this study has not been to generalize the results but rather to gain increased insight into and understanding of the phenomenon being studied. Furthermore, the research aims to provide the necessary backdrop for others through a holistic approach, and the author hopes that the findings could be used in further research.

4.4.3. Reliability

Reliability has a strong link to replicability and refers to whether another researcher who uses the same methods will be able to arrive at the same results. If the study has a high degree of reliability, it will also strengthen the study's validity because the study's conclusion is drawn from the collected data material (Halvorsen, 2008, p. 68). In qualitative research, especially through interviews, it may be doubted whether reliability can be achieved. It would be impossible to replicate the exact same setting as the relationship between informant and researcher would change and cannot be recreated. Jacobsen (2005) points out that it is therefore impossible to repeat the same findings in different ways. It is, however, possible that some forms of reliability can be achieved as the study has a strong focus on theoretical methods and procedures. Jacobsen (2005) further states that qualitative research is research that can provide a high degree of conceptual validity. The reason for this is that it is those who are interviewed who define what is the "right" way to understand a situation, as the answers are based on their professional knowledge. The interviewees for this study were perceived as outspoken and honest during the interview situation. The overall impression is that all informants, to a large extent, gave both complete and sincere answers, which limits the study's reliability problem. All interviews were recorded, transcribed, and sent back to the informants for approval. The transcript gave a complete reproduction of the content in the interviews, and the fact that all the interviews were approved also enables the possibility of checking the credibility of the conclusion. Thus, it is thought that if other researchers focused on the same theory and asked the same questions, it is possible that the conclusion could be similar without being completely identical.

5. RESULTS

The following section presents the findings ascertained from the semi-structured interviews. The empirical material will be systematized under the main categories according to the questions asked in the interview. Comments from the observation will help to supplement and build on some of the informants' statements. The results presented will contribute to answer the study's research problem: *How to ensure that facility-specific competence is present in an emergency preparedness organisation*?

To best serve the purpose of the research problem, the various questions from the interview, and subsequent results, have been gathered into five categories. The categories are constructed based on the nature of the questions presented, as well as the core concepts elicited from the participants. The five categories are as follows: Section 5.1, *Operational and organisational barriers*, Section 5.2, *Linking the identified barriers to emergency preparedness*, Section 5.3, *Facility-specific challenges in the EPA*, Section 5.4, *Facility-specific competence*, and, lastly, Section 5.5, *The PSA and The Industry*.

It is important to note that the categories and the division of findings are not excluded or unambiguous. In other words, data materials can in all probability also be placed under different categories and across themes. As presented in table 2, the informants posit different areas of expertise. Thus, not all informants will be included in each section, as not all of them have the relevant background to answer the questions. The reader will first gain insight into the reflections of the different operating companies and the company conducting security-studies before the reflections from the PSA are included in section 5.5.

5.1. Operational and organisational barriers

As there is no agreed upon definition of the barrier term, the first questions (question 1 and 2) were asked to establish how the different companies choose to define the operational and organisation barriers, and furthermore, how they identify the different barrier elements. This was done to create a foundation to better understand how the different companies understand the concepts and how they, based on their understanding of the barrier elements, choose to tackle the concerns raised by the PSA.

5.1.1. Defining barriers

Through the interviews, when asking how companies define operational and organisational barriers it becomes evident that most of the companies have defined both the operational and organisational barrier element. They are also closely linked to the way the PSA have defined them in the barrier memorandum (2017b), which is evident in the answer from P1, who stated;

> *"Operational barriers are where one must have an intervention or a contribution from the personnel on board (...) each operational barrier element is linked to an organisational one. We have said that if you have an operational requirement, there must be an organisational*

requirement that ensures that you have the right person with the right training who can do the job".

Nevertheless, as a consultant company that works with several operating companies, informant P5 mentioned that they do see variations in how the terms are used, even though they themselves prefer to focus on the definitions suggested by the PSA. However, even though the variations might differ slightly, the overall understanding of the terms are much the same. The informant explained that;

> *"It may vary slightly from customer to customer - how they want to use definitions. (...) there are some companies who choose not to emphasize organisational barriers to such an extent. (...) Instead of including them as two different barriers (operational and organisational), some choose to include the organisational almost as a performance requirement for the operational barrier element".*

Different definitions could be a result of the lack of agreement surrounding the terms. It could also possibly imply that the fundament for developing various plans and analyses also varies, but as one of the companies included in the study had another way of defining the two barrier elements, it became evident that they still include much of the same information, but they formulate it slightly different. Informant P2 explained this through;

"(…) *there has been a lot of frustration around the term barriers - what are barriers / what is not a barrier? (...) we have chosen to merge operational and organisational barrier elements into operational ones. That is, we only call it technical and operational [barriers]. In practice, this means that in the same sentence when we talk about an operational barrier element, we also say who will do it, i.e., the role".*

This indicates, that despite having slightly different formulations when defining operational and organisational barriers, the same viewpoint is adapted. The companies are all working on identifying both the operational barrier elements and the personnel needed in carrying out specific actions for the realisation of the barrier element.

5.1.2. The identification of operational and organisational barriers

In discussing the role of, and to what extent companies use the QRA and other risk assessment techniques when identifying the operational and organisational barriers, all the informant with background knowledge relevant to answer the question stated that the QRA is somehow included in the work of barrier identification. It was thus mostly mentioned in combination with the EPA when used as a tool to identify potential MAH, indicating that the QRA on its own could be challenging to work with. This was further supported by informants describing the QRA as 'overwhelming', 'technical' and 'based on statistics'. Additionally, some highlighted that the QRA often is used more in the design-phase of a facility than in the operational-phase. However, as the QRA contain a lot of information regarding the design of the facility, it was still included as an important document. The consultant company emphasised that they often used the QRA in both new projects and in the operational phase. Informant P5 stated that;

> *"(...) the PSA is very concerned about this area-specific focus and the overall control of risk, so then we must use the information available in connection with risk assessments to create the area-specific overview. So, to that extent I would say that we very much use the results from the QRA/ other risk analyses to make that overview in the barrier strategy".*

The informant also mentioned, when asked if they use the same approach both in new construction projects and in operation, that;

> *" (...) I would say that the approach is relatively similar, but you have a greater degree of details the later in the process you are. In the beginning, it tends to be a bit overwhelming because not all design choices are in place yet. The strategy must therefore be updated afterwards if any changes have been made to the barrier strategy".*

The final statement from P5 is also to some extent supported by the answer provided by informant P1, who emphasized that the QRA is an important tool to gain an overview of the area-specific challenges. The answer, however, also brings forward that only looking at the QRA is not enough to identify the different operational and organisational barriers. P1 argues that;

> *"It [the identification of barriers] is related to the QRA, but it is not something that is derived from the QRA directly. In the project phase, in the work with the risk analysis for the facility, we have created area-specific strategies for different barrier areas. A barrier area is an area that is representative of one or more types of accidents. The installation is then divided into different areas that represent a type of major accident or a set of major accidents that are representative of those areas".*

What informant P5 and P1 argues, suggests that the QRA provide valuable information for the preparation of the area-specific strategy as it divides the facility into different areas in the analyses. However, while the QRA continues to be an important document for the consultant company in the entire life cycle of the facility, operating companies tend to put more focus on other analyses when the facility moves from a project-phase over to an operational phase. Informant P1 described this through;

> "*We do not use the QRA from day to day in operation. The QRA describes a kind of basis for the overall risk related to working there and works more like a verification that indicates that it is safe enough to work there. On a daily basis, we must always try to relate to the changes*

that are happening and the new operations that are taking place, and always make sure that we keep the risk level as low as possible. We do this through continuous operational risk assessments, but we do not use the QRA for this as it will not provide much value as the QRA is mostly pure statistics".

The answers provided by informant P5 and P1 both indicate that the QRA to a large degree is used in the early stages of new projects. As P5s company also delivers barrier strategies in the operating phase, the QRA is commonly used when identifying the different barrier elements both in project and operation. Both informants do, however, agree that the QRA on its own is not sufficient in identifying the operational and organisational barrier elements, as P1 stated that it to a large degree is focused on the technical systems and barriers. This is also supported by informant P3, who stated that;

"The QRA is largely based on assumptions early in the project. This can change over time and is not always as easy to catch. The QRA is also a large document, which is difficult to update. Therefore, we often go through other sensitivities to give us a better understanding of the risk level on the device. (...) the QRA largely defines the technical systems and barriers associated with them, but not necessarily the operational and organisational barriers that must be in place".

Informant P3 continued to explain how they use the QRA as a tool to identify the organisational and operational barriers, as they first look at the technical systems they have and identify whether there is a need for manual operations for the barrier to work. However, the informant also stated that they use the EPA to identify additional performance requirements that might be necessary for the barriers to function as they should. The informant added that the EPA to a large degree also is based on the QRA. The company presented by informant P2 has recently tried to implement the same the same process on all its facilities to identify the operational barriers, and explained that;

"*We actually use all available information. Basically, when we identify the operational barrier elements, we take all available information as our starting point (safety strategy, HAZID, HAZOP, QRA, EPA, LOPA, etc.), everything we have as possible candidates to identify them".*

The informant then proceeded to elaborate on the work they have done in recent years, where the aim has been to identify all operational barrier elements on all the operating facilities, as well as in new projects. The informant explained this through;

"(...) in a project phase the use of analyses is much more detailed, in relation to human factor analyses etc. The purpose is to use it [the analyses] in the various steps in the project to, for example, be able to design a plant that has as much automation as possible. In addition to

> *using it in the design of a facility, it has another purpose: when the project is finished, we then deliver a safety strategy, a very important document for us, which is the plant's own safety strategy. It contains all the technical and operational barrier elements. This is how it is handed over to the operation, but then we have seen through, for example, workshops for operating personnel afterwards, even at completely new facilities, that we have had to make adjustments. You could say it is the transition from the theoretical to the practical".*

The informant explains how they have set up different workshops for the facilities to be able to identify all the necessary technical and operational barriers. The informant emphasises that even though this work is more demanding and detailed in a project-phase than an operating-phase (due to the amount of available information regarding actual operation), adjustments are needed regardless of when the barriers are identified. This also supports the conclusion brought forward by the three other informants, that the QRA and other analyses are used in the identification-process, but alterations are often needed when transferring the identified barriers over to the operation of the facility.

This implies that the QRA is an important tool for the further work of establishing not only barriers, but also emergency preparedness, as the area-specific overview creates a good starting point for the identification of necessary measures. Nevertheless, the actual information in the QRA is highly technical, and builds on assumptions. Therefore, it also varies to which degree the different companies include the information derived from it in the different stages.

5.2. Linking the identified barriers to emergency preparedness

Going forward, two questions (question 3 and 4) where then asked to uncover how the different companies made sure that there is consistency between what was identified as necessary measures through the barrier elements, and the actions carried out in an emergency. Additionally, the author wanted the informants to elaborate on how they ensured that facility-specific challenges were included in the identified measures.

5.2.1. Transferring identified measures to real actions

A part of the challenge with barriers and emergency preparedness is to transfer the identified measures into actions in a hazard and accident situation, to bring it from a written plan into action. In discussing how the companies ensures that there is consistency between the identified operational and organisational measures and the actions that are carried out in a hazard and accident event, the link between the identified measures and the EPP was highlighted. The terms *performance requirements, GAP analyses, DSHA and training and exercise* was also mentioned. Linking the identified measures to training and exercise and performance requirements was by informant P1 argued to be a good way to solve it, and was expressed through the statement;

> *"We have identified the operational barriers we have through barrier management and the barrier hierarchies. The entire list of operational barriers is provided as input to the*

emergency plans. All this is embedded in the training material and in the emergency preparedness exercises". The informant continued to explain how they arrived at this process; *"The detailed performance requirements we have are a consequence of a larger study done in retrospect where we have gone through the entire barrier structure. In the past, it has been challenging to train people due to a lack of clarity in the performance requirements, it has also made it difficult to provide unambiguous training and verify that the necessary functions have been fulfilled. We have therefore gone through all the points and given clear qualitative requirements that are verifiable. Then we have gone through all the points and verified them against the EPP".*

Informant P2 continued to explain how they addressed the same challenge in the workshops they did for all their facilities;

"*We actually do this through a GAP analysis, where we typically have 50 operational barrier elements [on average on each facility] that we have ended up with in the safety strategy, and then all of them go through a GAP analysis to determine which of them we have control over and how we have control over them".*

The informant also added that this is how they link the identified operational barrier elements to the emergency preparedness. Going forward, informant P2 explained how they identify if they have control over the operational barrier elements;

"(...) When we sort the operational barrier elements, we may see that we have control of 30 of them through emergency preparedness exercises and training, then there are perhaps 10 we have control over through simulator training for SKR operators, and then there are maybe 1-5 we have control over through exercises elsewhere (15 minutes scenarios etc). This is to avoid duplication of training. There must be compliance [between the identified elements and the actions in the EPP]. However, we sometimes see that there is a lack of correspondence between what has been identified as an operational barrier element and, for example, an emergency preparedness action. Then we must fix this in the EPP".

Informant P5 emphasised that in order to ensure compliance between the two areas, the responsibility needs to be shared between those who deliver the supplier of safety-services and the operator, and stated that;

"If there is a discrepancy between what we identify and what is actually done in an incident, I would say that we have done a poor job. It should preferably match. (...) Then the operators, for their part, must ensure that they have prepared the organisational barrier elements to carry out the [tasks identified through the] operational barrier elements in operation. This can be i.e., a DSHA, training and exercise. Then I would prefer to see that the operational

barrier elements that have been identified from our side should be covered by the various trainings [set up by the operators]".

This suggests that all companies try their best to include the barrier elements identified in various analyses into plans for training and exercise. This is first and foremost to ensure that there is consistency between what has been identified as the actions carried out in an emergency preparedness situation, but also to uncover if there are identified measures that do not work as intendent when tested in a scenario. Thus, the work in this stage also contribute to identify areas that needs to be improved or changed.

5.2.2. Including facility-specific challenges in establishment of barriers

In discussing how the relevant performance requirements for the operational and organisational barrier elements includes facility-specific emergency preparedness challenges and solutions to handle these, all four informants concluded that the different challenges are well covered through different processes including the involvement of the *EPA/EPP*, *DSHA* and *work meetings/workshops*. Informant P5 stated that;

"*The operational barrier elements that have been identified will often contain tasks that are covered by the EPA and are identified there. The EPA is specific to the facility. In addition, we use the EPP for every facility to ensure that they [challenges] is taken care of in addition to input we have received from personnel through interviews. So, I would say that the facility-specific emergency preparedness challenges are well taken care of".*

As the EPA builds on the QRA, this implies that a lot of the information identified through the QRA also lays the foundation for including facility-specific challenges. Nevertheless, as the QRA has been argued to be too technical in previous sections, the interviews mentioned by informant P5 in the above statement is thus likely to be crucial for including relevant information regarding facility-specific conditions. Informant P1 has a slightly different background as the company currently only operate one facility and stated based on this that all their analyses and plans are facility-specific, and thus contains facility-specific challenges. The informant continued to argue that this work might be more challenging for those companies who operates several facilities.

Informant P2 answered how they have tackled the challenge presented by P1 above;

"*The workshops were carried out at facility level, so then we had facility-specific expertise in the workshop. We often go in with a kind of generic operational barrier elements, but then they [each facility] have to make it their own. In some cases, we have to change some things. For example, the emergency shutdown system and the emergency shutdown hierarchy will be vastly different for different facilities. Including the facility-specific emergency preparedness challenges in the performance requirements is in this way handled".*

The two answers above indicates that it might be more challenging to gain an overview of facility-specific challenges when a company operates several facilities. Furthermore, what was stated by informant P2 indicates that companies try to develop a set of generic analyses and plans, and then go through so-called workshops to adapt them to each facility. This suggests that a lot of the input-data and information might be the same for different facilities. Informant P3 explained that they have tackled this challenge by conducting various work meetings, and stated that;

> *"We ensure that relevant facility-specific performance requirements are defined to handle facility-specific emergency preparedness challenges by establishing separate work meetings with the offshore organisation in the establishment of PS (Performance standard) for operational and organisational barriers, where each emergency phase for the relevant DSHAs is reviewed. We also identify which technical barriers that are necessary to handle the incident and assesses whether there is a need to define operational and organisational performance requirements to ensure the handling of an emergency incident".*

The informant further explained that all operational and organisational requirements must be defined in an operational document that describes the action pattern in an error, danger and accident situation (EPP, alarm instructions, warning matrix, operational procedure, etc.). In addition, informant P3 stated that personnel should have knowledge of facility-specific performance requirements through either courses or training offshore.

The answers implies that all the companies to a large degree ensure that facility-specific challenges are included in relevant performance requirements by conducting workshops or work meeting with personnel that have knowledge and competence regarding the different areas and barrier elements.

5.3. Facility-specific challenges in the EPA

As the EPA lays the foundation for the establishment of the emergency preparedness organisation, it was also interesting to discuss how the companies include the barriers in the EPA, and moreover, to what degree they focus on the facility-specific challenges when conducting the EPA. The following two sections presents the answers from question 5 and 6.

5.3.1. Including the identified barriers in the EPA

In discussing how the operational and organisational barrier elements are included in the design of the EPA, which informant P3 to some degree answered in the previous question, informant P1 stated that;

> "*I would think that it is perhaps the other way around, that the EPA provides input to the operational barriers. The result of an EPA is often a set of performance requirements, and they will affect how we organize our operational and organisational barriers. But when there are updates in the EPA, the various barriers [that are affected] will be known. There must*

therefore be a red line running through barrier management and emergency preparedness. We have thoroughly reviewed the operational barriers we have and included the EPP in what we have now looked at here".

Informant P2 also emphasised that a solid link between the different processes is important, and explained that;

"*There must be a red line there. The EPA is based on the risk analysis. In that sense, the safety-critical tasks that are relevant to a DSHA must be included in the EPA, but as we know, the operational and organisational barrier elements also exist beyond what is emergency preparedness. In a set of operational barrier elements, maybe 30-40 of the 50 (to take a number) are covered by emergency preparedness. But the emergency preparedness analysis itself is done with its own management and on the basis of the same documents as QRA".*

Thus, it is again highlighted that the work of establishing barriers and emergency preparedness builds on the information derived from the QRA. Informant P4 also outlined how this is a collaboration between several departments, and highlighted the role of the QRA in identifying and including the operational and organisational barrier elements in the EPA;

"We receive the QRA from the Technical Safety department, and a good number of things are listed there, including the various barrier elements that we have to deal with. This is therefore based on the analyses from technical safety, which covers how this [the barrier elements] should be implemented and how we should handle an incident that triggers a DSHA at our different facilities".

What informant P4 stated above, indicates that the information needed in identifying the operational and organisational barriers are handed over from another department, which again provides a clear division between the technical and the operational parts of the facility. Thus, ensuring that the personnel working on the facility fully understands the information provided to them by the technical safety department could possibly be a new challenge. Informant P6 talked about how they usually proceed when working with various operating companies and mentioned that they are depended on information from the work meetings between them and the other company in order to include the right barriers. The informant stated that;

" (…)we often get a set of performance requirements that are predefined at company level, and then we see if they fit the analysis that we have done - or if we have to adjust them, for example, if the facility is large or small. This is done so that the time requirements add up. For each individual DSHA, we go through the emergency preparedness strategy and how we intend to handle the DSHA".

The informant explained that many of the operational and organisational barriers are identified based on experience, but that many of these are reviewed in the work meeting regardless. The informant then elaborated on how they do adjustments in the analyses they have done;

> *"(...) [in the work meeting] it emerges how they [the operating company] want to do things/how they do things. Then we do an adjustment in that area. An example is that a man overboard incident is discussed, where someone adds that they then must stop the thrusters, so that a man overboard does not end up in the thrusters. This is a facility-specific challenge, as only floating installations (rig or FPSOs) are equipped with thrusters".*

This also implies that much of the work linked to the identification of barriers and associated performance requirements often builds on the technical calculations done in the QRA and the outcome of the EPA. Furthermore, the communication between those who conduct the analyses and those who will perform various actions in an emergency preparedness situation is vital in ensuring that the right performance requirements have been included. Thus, as emphasised by some of the informants, keeping the red line from the QRA to the identification of performance requirements for operational and organisational barriers is important.

5.3.2. Identification and focus on facility-specific challenges

When asked to what extent the focus is on facility-specific challenges when the EPA is established, and how the various challenges linked to emergency preparedness is identified, the focus on the *DSHAs*, *EPA* and *QRA* are again brought up. Additionally, the consultant company stated that the correct *information* again is a crucial factor to include facility-specific conditions. Informant P6 stated that;

> "*We look at emergency preparedness challenges for each DSHA in the work meeting. We have a number of things that often recur, but then it may be that facility-specific challenges emerge in the work meeting if they [the operating company] come up with something where someone has to do something with a specific type of equipment for a system to work. The facility-specific challenges are thus identified in the work meeting, and it therefore depends on what input we get".*

This implies that based on challenges that often occur, it could be possible to create a generic starting point for the consultant to use. Nevertheless, as they do not have the knowledge about facility-specific conditions, they are dependent on the personnel to give feedback of which additional challenges that need to be included. The informant continued by stressing the importance of the input data;

> "*Our wish when we arrange a work meeting is that we have personnel with operational experience from the facility for which the analysis is prepared. It is however just a wish from*

our side, and we cannot control who is at that meeting. Those who work at the facility may also know where the impairments are. It is not information we can be familiar with unless we get input about it".

This implies that facility-specific challenges might be left out of the analyses if the consultant companies do not get the information they need. Nevertheless, as several have highlighted earlier, the final analyses and plans delivered to the companies should always be possible to update if something else needs to be included. Further, P1, P2, P3 and P4 all agreed that the EPA must be facility-specific and thus, must have a strong focus on the facility-specific challenges. P1 stated that;

"*(…) [the EPA] cannot be made generic, and it must be based on the QRA and facility-specific conditions. Emergency preparedness challenges will be identified through an analysis of the emergency preparedness organisation and the emergency preparedness equipment available".*

Informant P2 supported that the various challenges are identified through the EPA and stated that;

"I would like to think that this is a prerequisite because the emergency preparedness analysis also provides a dimensioning of the emergency preparedness organisation. Thus, it must be facility-specific".

Informant P3 also elaborated on how they identify the various challenges, and included several points they focus on in the identification process;

"The challenges are identified through the identification of deviations in design (temporary or permanent) results from risk analyses (HAZID, QRA, sensitivities, etc.), findings from barrier mapping, verifications or inspections, learning from incidents and near incidents (internal and external) and the experiences of operational personnel at the facilities".
"However, it may be difficult to find relevant facility-specific challenges during an EPA. We see through investigations, audits and verifications that challenges may have been overlooked or not completely understood".

Informant P4 explained how solutions for one facility not necessarily work as a solution on another facility, to highlight that it is not possible to create generic plans without a facility-specific focus. The informant emphasise that it is important to look at more than just the EPA, and stated;

"We must look at what is in the QRA, what previous experiences we have, what various inspections the facility have undergone, it may be that the PSA has been out and carried out

an audit and given feedback that we must come up with another solution. (…) we try to make the EPA facility-specific as far as possible (…)".

The answers provided by the informant suggests that there is a lot of information that needs to be included in addition to the information derived from the QRA for the facility-specific challenges to be identified and covered in the analyses. There is however, no way of knowing if all necessary information actually has been brought forward, which is likely why many companies uses various sources to collect relevant information. Furthermore, this will ultimately lead to a lot of information, where the work of finding out what is relevant for various challenges is both challenging and important.

5.4. Facility-specific competence

As the PSA stresses the need for personnel to have knowledge about facility-specific challenges and the barrier elements that are identified to handle these, the following section is based on question 7 and 8 in an attempt to map how the various operating companies ensures that the information derived from the different analyses and plans are transferred to the personnel. Furthermore, how they ensure that the needed competence to handle the identified facility-specific challenges is present amongst the personnel will also be presented.

5.4.1. Knowledge regarding the facility specific challenges

When discussing how the companies ensures that the facility-specific challenges identified through the EPA and the different barrier elements are known amongst the personnel on the facility, focus was put on the *EPP* and identifying which *personnel* that would have to be familiar with the various challenges. Informant P1 explained that the EPP is a crucial source of information for their personnel, and stated that;

> "*Based on the EPA, EPPs are made that provide information on what the emergency preparedness function should do in an error, danger and accident situation. (…) There are also system descriptions that are made to describe what the emergency preparedness teams are intended to do"*.

While informant P4 also highlights the EPP as a crucial source of information for the personnel, informant P2 argued that it first and foremost should be established *who* needs to have this type of knowledge;

> "*We must distinguish between those who have a specific role in an operational barrier element and those who do not have a role. Those who have a specific role should know their barrier elements and their role, as well as [have the necessary] training in it, etc. Those who wash cabins do not need to know operational barrier elements for other roles. Nevertheless, they should know the tasks that are relevant to them (if they have any"*.

Informant P2 further stated that a lot of the necessary information is gathered in what they call internal platform verification. The informant explains that the internal platform verification should contain everything you need to know to perform the operational barrier elements in a prudent manner. Finally, the informant emphasised that they might be more depended on people doing what they are supposed to do in an emergency situation, than making sure that everyone has the knowledge about all the various challenges. The informant explained this through;

> *"Everyone can not necessarily know everything, and sometimes people may train on what they call an operational barrier element, but they do not know exactly why they train on it. Their understanding of the situation will depend a bit on how good an explanation they get on the "story" the training is based on. As long as people do what they are supposed to, I think it is not always necessary for everyone to know the content of the QRA. It is more important that they know what to do in a situation. They must, however, be aware of the risk(s) related to the activity they are doing".*

This implies that for the company it is more important that people know what to do and when to do it, than them having a full understanding of the total risk picture for the facility they work on and all the associated facility-specific challenges. It is thus possible to ask questions surrounding if some of the deviations related to competence brought forward by the PSA can be a result of vague guidelines for how much knowledge and competence various personnel is expected to have. Informant P3 explained that they currently are working on creating a database to gather the various challenges in order to create a broader overview. The informant stated;

> *"(...) we are working to establish a scenario database for all DSHAs for our facilities. These will be built around the emergency preparedness challenges that have been identified to ensure knowledge of challenges and that these are used for training".*

A database such as described by the informant above could be a useful tool for the personnel to use to be aware of different facility-specific challenges. However, if these challenges can be incorporated into the training and exercise done at each facility, relevant personnel with specific roles linked to the various DSHA should also gain knowledge about the challenges through this.

5.4.2. Competence to handle facility-specific challenges

All of the informants agreed that the best way to ensure that personnel have the relevant competence to handle facility-specific challenges is through training and exercise. Informant P1 stated that;

> *"[The EPP] will provide a basis for training material for the emergency preparedness teams, not only as training and exercises offshore, but the emergency preparedness teams also have*

a calendar-based training program they will go through. This training program is based on NOROG's [Norsk Olje og Gas] modules, but it also contains knowledge of the system descriptions that are facility specific. (...) It will thus be part of the training - to ensure that you have the local knowledge".

Informant P1 then elaborated on how they ensure that the relevant personnel have the right competence to handle various situations;

"*Continuity in the organisation is also important, and only the permanent employees have the emergency roles offshore, but then it is important to have continuous training over time. Regular calendar-based training, in addition to exercises, both of which are facility-specific"*.

Informant P2, P3 and P4 also point to the set-up of emergency preparedness training and exercise as a crucial factor for the facility-specific competence. P4 also emphasised the importance of continuous training over time;

"*You practice on such challenges every week. Additionally, you sit down and make a plan at the beginning of the next practice year to get an overview of what types of events to train on. Then we will add exercises that make us train specifically on a problem, on a weakening of a barrier for example"*.

The answers suggests that the companies ensures that the personnel have the right competence through training and exercise, either at individual level or as an emergency preparedness situation. The training and exercise are thus built on the EPP/EPA/QRA, which again brings us back to the importance of the right information being included from the very start. Facility-specific challenges and associated competence to handle these in an emergency preparedness situation will not be included in the training if they are not identified.

5.5. The PSA and the industry

At the end of the interviews, the interviewer asked a set of more general questions aimed at current procedures. The purpose of the questions was to get the informants to share their thoughts on the increased focus on facility-specific competence and the methods and procedures being used in the industry today. Questions 9, 10 and 11 were asked to understand how the companies understand the overall situation and to highlight potential strengths and weaknesses in the procedures being used today. This section also includes answers provided by the PSA to compare how today's situation is viewed by the industry receiving the regulatory requirements and the supervisory authority issuing them.

5.5.1. Views on current methodology

When asked about possible points of improvements in the current methodology used in the industry to better include the facility-specific challenges, the informants mentioned different focus areas. Many of them highlighted the topics of *input-data, access to information, methods being too generic* and *the overall work process*. When discussing the input-data, it was both mentioned as an opportunity and a challenge. Informant P5 stressed the importance of input data from their customers, which was elaborated by informant P6 who stated;

> "*We are one hundred percent dependent on our analyses revealing the conditions that actually exist. A weakness in current analysis is that we conduct several interviews, but if they happen to omit an important factor in the interview, then we won't be able to include it [in the analysis].(...) That weakness always exists"*

However, informant P5 continued to explain how the analyses continuously must be followed up to ensure that they stay relevant. The informant also said that even though the access to relevant information can be a weakness, it should always be possible to add potential lacking information through a feedback loop to include it in the overall analyses and plans. Answering the same question, informant P1 mentioned more mapping and input-data can always help improve the overall overview, but it might also come with some challenges;

> "*(...)but the more details, the less ownership you get externally. We try to create something that the operating organisation owns and manages to relate to. It will still be possible to provide more input on status, even if we ourselves (I would say) have almost gone too far in detail on fragmentation and barrier hierarchy. We could probably have come just as far with a coarser division, while now there is a lot of work with too small details, and in the end, you can end up losing some relevance".*

In the above quotation, P1 stressed that what could be an improvement in the current methodology also can end up being a challenge. Just like P5 and P6, P1 chose to focus on the amount of available information and the level of detail. Informant P2 seemed fairly confident with their established methods, and stated that;

> "*Those who have completed internal platform verifications and succeeded, they have both increased the focus [on facility-specific competence] and improved their operational barrier elements, where they see that they either lack some or have to change those who already exist. There is nothing wrong with our management and methodology, but it is about doing it in a good way and setting aside enough time".*

The informant concluded that the method for establishing the necessary information is solid, but those faced with the methods must have an understanding of how to use it in order to get the most out of it. This implies that there also are challenges linked to transferring what has been established through workshops over to how operations are carried out in practise. The confidence in P2 answers, and the challenges brought forward by P5, P6 and P1, is summed up by P4, who emphasise that an improvement could lay in the flow of information between different companies. The informant stated;

> "*My answer must be that you then could merge information between operating companies. (…) if different operating companies talk to each other and find out how a challenge should be tackled so that it can suit everyone. That you work together on requirements that are possible to achieve. We have started to talk a little more together and we have become better at collaborating on things in recent years, but it could get better".*

This answer is somewhat linked to informant P3s response; *"I believe that today's analyses to a large extent can be too generic, and that there is a need to understand and identify relevant emergency preparedness challenges in order to be able to handle an incident*". The informant further stated that the work of identifying the facility-specific challenges often involves a lot of data and complex connections, which might lead to that the various scenarios are not fully explored. Additionally, the informant mentioned that the QRA is carried out to verify a type of design against a predefined acceptance criterion, it assumes that the technical measures work and has little or no focus on operational and organisational performance requirements needed to handle an incident. The two answers from P3 and P4 suggests that the theory and methods used in the industry might be too generic to identify facility-specific challenges. Instead of focusing on following a set methods, the industry could possible come a long way by learning from each other and sharing experiences with how to uncover the various challenges.

The PSA highlighted different point of view, which brought forward that the analyses and methods used are to a large are centred around the same scenario;

> P8 "*The main problem that we may have seen in recent times is that everything around barrier management is established based on one scenario, namely hydrocarbon leaks. Other scenarios that may happen do not fit well into the methodologies and standards for this. It should have been further developed so that the methodology used is scenario-free".*

P6 followed up and argued, similar to P3, that the standards used in the industry are solid when linked to the technical conditions. However, as the standards gives little information about how to handle operational and organisational conditions, these have a stronger ink to the companies' internal mapping processes and barrier management processes, the informant stated that;

> *"You can always get better at mapping, and you always have to make sure to involve the right people related to the right scenarios. (…) one will never be able to map 100%. For me, it is more about the interaction between the various processes in a barrier management process,*

> *which intervenes in so many work processes in a company, and that it is rather the red line there that can be strengthened more than the analyses and methods behind it".*

This implies that facility-specific challenges linked to events that fall outside the area of hydrocarbon leaks might be even more challenging to identify. Furthermore, it highlights that the industry might be so focused on fulfilling the various requirements within each area that they struggle to connect the entire process together. When discussing the areas of improvements, the interviewer asked the follow-up question; "*Do current analyses provide a sufficient basis for identifying challenges and measures?"* to which P5 and P6, representing the consultancy company, argued that the methods used are designed for them to capture pretty much every big event that can occur. Informant P6 then followed up their mutual agreement and stated;

> *"It is built for us to be able to handle the big events, and if you can handle those, you can handle all the small ones as well. However, you will never be able to create a perfect emergency preparedness strategy because every incident is unique".*

Informant P4 supported that the external companies that often carry out the analyses for the operating companies do a thorough job and saw this as a good way to solve it as long as the right personnel with the right competence is involved and the information is communicated clearly between the different actors. The PSA argued that the analyses are full of relevant information, but that the information available often are very technical. Informant P8 argued that;

> *"(...) there is a lot of this analysis tool that can perhaps be called a bit theoretical or academic, and in order to translate the information into what the facility needs, you have to get it «off- academicized » quite a lot. And that's probably the problem, to get it from good analysis to practical work (operationalise it)".*

Informant P9 mentioned that they see cases where some scenarios have not been included, and thus, that potential challenges and necessary measures are not identified;

> *"(...) we sometimes experience that they [operating companies] say that they make some assumptions. They say that this and that type of event is so unlikely that they do not even look at it. They then choose not to go further and analyse those scenarios. (...) There is a very low probability of all major accidents, but when you make such delimitations in these analyses, this also goes into the methodological work, where you make certain delimitations that cannot always prove to be justified".*

It is thus, again, argued that the analyses work well as long as the people using them do so in the right way. In relation to what P8 stated above, informant P9 also mentioned that they try to help make sure that the analyses uncover the right type of challenges and measures, and that there is a red line between the different disciplines onshore and offshore. The informant stated that;

> *"(...) we sometimes try to use individual incidents as a starting point to get everyone offshore and onshore involved. Then we might ask "if this type of incident happens, what barriers do you have? What is their role? What analyses have been done in advance related to this scenario?" And that you then take it all the way out to sea to the facility and ask who does what with what equipment in this situation and how they check that they get this done?".*

This implies that the analyses and methodologies are designed to capture the various challenges and associated measures linked to a facility, but in order to uncover these, the information in the QRA needs to be fully understood. When working as a basis for several analyses and different areas of mapping, making sure that the relevant information for each area is identify could serve as a major challenge.

5.5.2. Balance between facility-specific competence and basic skills

The final question that was asked to all relevant informants was related to possible challenges with the increased focus on facility-specific competence, and if a high focus on facility-specific challenges and measures to handle these could cause them to lose focus on more basic skills needed when faced with an error, danger and accident situation. In general, all informant agreed that both types of competence should be present at all times. Informant P1 said it was hard to see any downsides with a high focus on facility-specific, which was supported by the PSA. Informant P2 stated that;

> "*We say that we must have both, you must have basic skills, while the operational barrier elements are and will be facility-specific. (...) In addition, employees rotate between installations, which on the positive side provides a transfer of experience between the facility, the disadvantage is that you get less facility-specific competence. Regardless, we have checkpoints for the safety-critical roles (...). You must go through check-out at installation level. That personnel have the right competence is registered in CAMS (competence assurance management system), where all the competence requirements are on offshore workers. Some of these requirements are very specific and thus provide a solid basis. (...) if you have a role in the emergency preparedness organisation, the DSHAs you train on are generic, but they are put into an installation-specific training and exercise".*

Informant P3 agreed that it is important to have both but emphasise that too many and strict requirements for training against facility-specific performance requirements might lead to that personnel train a lot on special events and that they lose focus on the basic skills of the emergency preparedness organisation. The informant explained that as the emergency organisation consists of regular operating personnel with an additional task to take care of the emergency on board and thus, that; "*It is important to balance the focus on facility-specific challenges against the performance we expect from the respective emergency preparedness functions".*

When discussing the same question with the PSA, they admit that they have gotten feedback from operating companies who reacted to their increased focus on barriers and facility-specific competence in terms of that it would be impossible for the companies to practise on every single possible event, to which the informant P7 from the PSA answered;

> *"(...) and that is correct, you cannot train on everything. Therefore, it is important to know what competence you get through your basic skills and what specific competence are not covered there so that you have to train on that on the side. Furthermore, one must find out which skills one must verify through training and practice".*

This implies that the PSA also means that facility-specific competence should have a strong link to the identified performance requirements for the operational and organisational barriers, as it in this way is possible to map the already existing competence with missing competence, through for example GAP-analyses. Informant P7 continued to explain what they actual talk about when they want the industry to go through exercises that includes facility-specific challenges;

> *"In the barrier memorandum, we write very clearly that it is the handling of normal operation which gets a lot of attention. What we have been worried about are these difficult, extra situations that you cannot test or train on in the daily situation. (...) The normal operation takes place daily, and then you practice on situations that fall outside the normal "everyday life". I do not think that we drain them for knowledge of basic skills by having to practice once or twice a year on the difficult situations".*

The informants then talked about how they see many examples where the lack of facility-specific competence has been a root cause for a situation to arise. The people involved have in general had a good general understanding of the technical functions of different equipment, but when they have been faced with a new area (on a new facility for example), their general knowledge is often not enough in specific situations. Informant P10 followed up by showing to a recent example;

> *"There was a fire in the mud lab at West Pheonix, and one of the biggest lessons for the fire department was that they did not know where the mud lab was. This is where the facility-specific competence comes in. That you must actually be familiar on board the facility you are. We have quite a few such examples".*

Informant P9 also stressed that a lot of the deviations are due to the lack of mapping in various situations. The informant brought forward the technical starting point for the mapping of various challenges and measures, which often led to a high focus on the equipment and associated tasks.

However, many forgot to look at the overall interaction between personnel. The informant explained;

> *"In a real event, there is considerable interaction between personnel, this interaction is often poorly mapped, and they are often very concerned with looking at the individual tasks themselves. Some people are good at training, for example with the help of table-tops, where they go through an event and discuss. They will often be able to gain a very good insight into the interaction and what equipment they must use during the event. But there are some challenges in relation to quality with being able to map the type of complex incidents, where you suddenly go out with new equipment or out to a new job at a facility where you have never been".*

In other words, it this implies that personnel need to have the basic competence, such as putting out an fire, but they also need to have the specific competence that is linked to the design of the facility and the area-specific risk picture, to be able to locate the fire and know how to handle it in that specific area. What the PSA highlight is that many companies will set up training and exercise to cover competence that is needed in events that fall outside the regular day-to-day operations, but they might not include the right elements into the training to cover enough of the facility-specific challenges.

5.5.3. PSAs viewpoints of current analyses and plans

Finally, the author wanted to hear the PSAs viewpoint surrounding to what extent they consider that the current analyses and planning covers a sufficient degree of detail to provide the right decision support in an error, danger and accident situation. *Generic analyses and methods* and *lacking the full overview* was brough forward as important factors. Informant P7 was very clear and stated that the operators do not have all the details needed, and that this is the basis for why they have started with other procedures, in order to gain a better foundation of details. Informant P8 continued the conversation and stated;

> *"I think that what is covered in the risk analyses of construction failure are based on a generic number. They have no facility-specific assessment covered in the risk analyses for construction. They take figures that SINTEF came up with at some point (…) At least they did for a long time. But when it comes to what they do on barrier management, we see more and more that facility-specific conditions are taken care of".*

Informant P7 then added that it is rather about the operators to know what to use the different analyses for, than to say that there is something wrong with the analyses, and that the tools for identifying the facility-specific competence are there, but they must include the right type of analyses and assessments. Informant P9 further stated that the way current analyses and planning are conducted in general builds on an extremely technical starting point for barrier management.

The informant went on to draw attention to those who often success in the work of mapping the facility-specific competence, and stated;

> *"What we have seen when it comes to mapping the interaction between technical, operational and organisational barrier elements, is that those who are able to identify which tasks must actually be performed at which place in the facility, they do a typical traditional task analysis where they assess if this and that is something that is done automatically or if it is a person who needs to be involved. And if so, with what equipment and where the task must be performed".*

Informant P7 also emphasised that the current analyses and plans in general have a very technical starting point, and that this might lead to challenges of transferring the right information to the right personnel;

> *"This is a very technical starting point with barrier management, and when you start talking about the operational part of it, i.e. who will walk the 20 meters and operate a specific valve, it is not guaranteed that this is something that the one who has technical knowledge about the valve are familiar with, but he has knowledge of the valve itself. It is often in the technical safety strategy that the operational action is described, but who is it then that ensures that the operation ends up in a plan or in a procedure and sees the connections?".*

This implies that is thus challenges linked to the various processes and ensuring that the red line follows the relevant information all the way from the identification phase to the operating phase. Informant P10 then emphasised what had been mentioned earlier, namely that the analyses are good, but that the focus need to be put on how the analyses and methods are used. The informant stated;

> *"(...) as in emergency preparedness analyses for example, the analysis is good, and there is nothing wrong with the method either, I would say, but there is something about the involvement of personnel. To ensure that it will not be a desk exercise for a group of consultants who sit on land with the land organisation, and then you may not involve those who work offshore who actually know the specific challenges. (...) it is something we are very concerned about, that they must involve those who actually work offshore".*

To sum up, informant P9 mentioned that they see both cases where good use of an analysis and good implementation of analysis can provide a good basis for decision-making. However, they also see that some use them in a more generic way, where they do more of a copy-paste without taking into account the facility-specific conditions. Finally, informant P7 used an example from a real training session that showed clearly that the error is not in the shortcomings of the analyses, but rather ensuring that the right elements from the analyses are included in the training and exercise scenario;

> *"They were going to practice on a major accident scenario, where there was a small, fixed facility with a jack-up that stood next to it (for drilling). Then they were going to practice what to do in case of a hydrocarbon incident on the small facility. In the design of the facility, some choices have been made which meant that the facility had to be evacuated quickly. They had not fully grasped that. It was stated in the analysis, it was certainly also stated in the planning, and in addition well described in the QRA – that you need to be off the facility within x minutes. Nevertheless, they chose to carry out search and rescue on the small facility and were very satisfied with the training results for search and rescue teams and first aid teams. They had not then realized that they were making a big mistake in the first place [by sending the team over to the facility]. It was inadequately described what they were actually going to practice in that exercise and what they were going to learn".*

Informant P7 emphasized that; *"it is not necessarily because the information is not available in the analyses and plans, but rather that it is not understood what is important elements that they must practice on".* This also implies what has already been mentioned several times, that many of the challenges linked to the various methods, analyses and processes are connected to the information in the QRA. There are thus fundamental challenges linked to knowing which information to use in which situation.

5.5.4. Going forward

As we live in a world that is driven by technological development, the author also wanted to ask how the informants think the future of barriers and emergency preparedness will look with regards to more digitalization. *Access to more information, drones, less exposure of personnel* and *barrier panels* were the areas the informants put most emphasis on. Most of the responses were positive linked to opportunities, however, the challenges of hacking and an overflow of information was also mentioned. Informant P1 highlighted their current development of the barrier panel and stated; "(…) *our vision is that we should be able to have a live risk picture [through the barrier panel available at the facility]. It is about barrier status, but we also want it to say something about the level of risk in different parts of the facility".* Informant P2 stated;

> *"There are really only opportunities, (...) what we see is that we have the information we need (technical impairments, operational impairments, and we have them sorted under different performance standards), but the big improvement and the opportunities that exist are to visualize these impairments in DSHAs with performance standards instead of presenting them in a flat list through the performance standards. (...) Digitization is important, but it is first and foremost the basic data that one must have control over. (...) For me, it is first and foremost about how we can use the information we already have in a better way".*

Informant P3 also mentioned the importance of the quality of the data, and highlighted both pros and cons;

> *"The development of digital tools and the operationalisation of data can greatly change how we analyse and handle MAH. More and better data can give us a larger and better decision basis for handling errors, danger and accident situations. However, it is important that the data quality is good and that we have a clear idea of which data is important to handle a potential MAH. The complexity of the data and too many different data sources can make it difficult to interpret the data".*

This implies that the challenges brought forward regarding the understanding of which information is relevant to a large degree is something the operating companies are aware of. They also acknowledge that getting control over the information they already have is something they still need to be better at. Informant P3 then added, in similarity to P1, that they envisioned that more digitalisations can lead to plans that give information about real-time status;

> *"I believe that digitalization can lead to functional plans that is based on real-time data instead of the current plans that are based on procedures established based on a more generic level and data with conservative consequences. Digitization will be able to improve the understanding of the situation and reduce the time for collecting data. This may mean that the emergency management has more time to assess actions in line with the methodology in the proactive method".*

Informant P3 also mentioned that they wanted to include the use of robots and drones into the emergency preparedness, which was also supported by informant P6 who stated that;

> *"I think it can lead to less exposure of personnel, if we can use robots and drones to explore an area that is not safe. Today we must wait until an area is safe before we send in personnel, and then we can sacrifice a robot / drone instead. That way, we can get a lot more information earlier which is valuable feedback to decision makers. It can be an extra aid, in addition to cameras and sensors that give us more input than we have today".*

Elaborating on the topic, P6 also mentioned that digitalisation and the use of digital twins for example can lead to better ways of training personnel and simulate a number of different consequences to be better prepared for how an event might develop. This was also something that informant P3 highlighted. The PSA stated that they understand that the industry wants to focus on new opportunities, and informant P8 stated;

> *"We follow up various digitalization projects, and sometimes people talk as if this is something they have [in place], and then you discover that it is almost a bit like a utopia, and then there are other times where we have also had a slightly opposite experience, and discovers that someone have come a long way in the project and we have not quite been able to follow".*

However, the PSA also emphasise that many companies struggle with the input data, and that this is something that should be the main focus. They are thus supportive of the development and mentioned that if companies can find a good way to solve the various challenges through the use of more digitalization, then nothing would of course be better. But as the various companies also highlights, a crucial point is first and foremost to have control and a good understanding over the data and information they already have available.

6. DISCUSSION

Allow me to summarise what has been presented in this study so far. Having a robust and solid emergency preparedness organisation is crucial in the work of preparing the personnel on offshore facilities to handle incidents that have the potential to develop into a MAH. It is indeed so important that the PSA have regulatory requirements that state that every operating company should ensure that they have established and at all times maintained effective emergency preparedness. An essential part for the emergency preparedness organisation to function as it should is that personnel must know what to do and when to do it. In other words, they need to have the right facility-specific competence to carry out actions in a failure, hazard and accident situation. However, the Norwegian petroleum regulatory framework works as a functional framework, meaning that it is up to each company to find out how to ensure that this competence is present. Making sure that the personnel involved in the emergency preparedness organisation have the right competence will largely depend on the input data retrieved from the QRA and the work of identifying barriers that need a manual operation to function.

The industry can use guidelines and standards as a helping tool in the complex work of mapping this. Still, these are developed so that every company should be able to use them, which makes them generic in their formulation. Ensuring that the correct information and data have been included in the analyses and plans to uncover the facility-specific challenges for each facility is thus the responsibility of each company. The aim of this study is not to come up with an answer to how this web of complex analyses and procedures can be done or solved, but rather to shed light on the challenges linked to facility-specific competence, attempt to uncover how various companies solve these and possibly find areas in the analyses and methodology used today that need to be highlighted or improved in order to ensure the presence of facility-specific competence.

The following section will try to analyse this through the main themes that were established in the semi-structured interviews, whilst analysing them against the theoretical backdrop of the study, presented in section 3. The subsequent research questions - *(R1) How do the operators ensure that the right barriers have been identified; (R2) How do the operators secure that the identified barriers and associated roles and actions are understood and performed by personnel?*; *(R3) To what extent do current analyses and methodologies provide sufficient information about facility-specific challenges?;* and, *(R4) What adjustments in the current methodology can be implemented to increase the focus on facility-specific competence?* - will be included in the structure.

As such, the following chapter will be segmented into five sections, building on these questions: Section 6.1, *Ensuring that the right barriers have been identified;* Section 6.2, *Securing that the identified barriers and associated roles and actions are understood and performed by personnel;* Section 6.3, *To what extent current analyses and methodologies provide sufficient information about facility-specific challenges;* Section 6.4, *Adjustments in the current methodology can be implemented to increase the focus on facility-specific competence*; and lastly, Section 6.5 will combine the finding to answer the research problem, *How to ensure that facility-specific competence is present in an emergency preparedness organisation*. Finally, section 7 will introduce some concluding remarks.

6.1. Ensuring that the right barriers have been identified

The role of barriers is crucial in minimising the risk of MAH (Lauridsen et al., 2016). Thus, the work of identifying them are highly important, and the outcome can have a significant impact on the consequences of an incident. The identification requires a comprehensive understanding of the risk picture related to the facility and/or the activity under consideration (Hauge & Øien, 2016). On one side, having the proper barriers in place at the right time can prevent a situation from developing into a MAH, as seen in the rapports from the PSA (2020; 2022). On the other side, insufficient identification of barriers might also be the root cause of the event occurring in the first place or escalating. This is, as mentioned earlier, especially apparent when focusing on operational and organisational barrier elements, as human error has been judged to be the main element that has failed in the defence in depth (Skogdalen & Vinnem, 2012; Jennings, 2019). It is thus crucial that the companies understand which barriers are necessary to identify, and that the methods for doing so include the correct background information regarding facility-specific challenges.

Nevertheless, due to the lack of agreement surrounding the term 'barrier', several companies have for some time struggled to implement a successful barrier management strategy (PSA, 2017b). Johansen and Rausand (2015) discuss that a special subject that has caused a lot of confusion is the meaning of operational and organisational barrier elements, where they argue that some view them as basically the same, while others say that it is necessary to maintain the distinction. They also state that "*there are also those who think that there are no such things as operational and organisational barriers, which is reinforced by the technical focus in the standards*". Through the interviews, it did, however, become apparent that all the companies understood the importance of operational and organisational barrier elements. Even though the definitions varied slightly (where one company had combined them), it was still clear that they all included both the action needed to be done, and the personnel that would have to do it when mapping the various barriers in relation to MAH.

As emphasised by Hauge & Øien (2016), the identification of the relevant barriers makes up a significant part of the design-phase in barrier management. Furthermore, they argue that the design and identification of the different barrier elements have a strong link to both the QRA and the DSHAs identified and analysed in the EPA and EPP. Thus, the identification of barriers can be said to have a clear connection to the pre-crisis phase of the emergency preparedness process. The nexus between the QRA and barrier identification is to a large degree based on the need for the barrier strategy to be area-specific and address the specific barriers against MAH in each area of the facility. When identifying the different MAH on an offshore facility, the QRA divides the facility into different areas (Vamanu et al., 2016), such as process area, riser area, living quarter etc. The area-specific risk picture then typically gives information about key equipment, rooms, wall configuration, wall fire and explosion rating and external escape ways which further provides input to the design of technical barriers that must be in place to ensure that the risk is reduced to an acceptable level.

The connection between the identification of barriers and the DSHA derived from the EPA then builds on the area-specific risk picture established in the QRA. The various DSHA are formulated based on the potential MAH that are identified in each area. Moreover, based on if the technical barriers identified in each area are dependent on a manual operation to function, the operational and organisational barriers are then identified. Overviewing the respondents' interviews showed that all companies to a large degree use both the QRA and EPA/EPP in their identification of operational and organisational barrier elements. However, as the QRA generally contains results based on numerical calculations that are used for comparison with the predefined RAC set by the operator and give information regarding the structure of the design (Proactima, n.d.), the information derived from the risk analysis is often very technical. Furthermore, it is argued that the QRA lack the necessary resolution to serve as a basis for establishing performance requirements related to operational and organisational barrier, and that it uses default, fatality-based risk metrics that are insensitive to many barrier functions (Johansen and Rausand, 2015). This was also a concern emphasised by the PSA, namely that the information in the QRA should ideally be "de-academized" before it is used as a basis for the EPA and EPP. Nevertheless, this challenge was something that the informants all seemed aware of in section 5.1.2, and was primarily the reason as to why several of them argued that the use of QRA was not sufficient in identifying the necessary operational and organisational barriers.

To tackle the challenge of making the QRA more "operational friendly" or to "de-academize" it as PSA highlighted, personnel with operational experience within the different facility areas are needed. As portrayed by several of the informants, this is commonly done through work meetings or workshops where personnel from several parts of the company and those who conduct the analyses sit down to talk through the findings. This is not something that only are done in the design-phase of a facility, but which should be done continuously. Another important factor highlighted by some of the informants was that the QRA was mainly used as identification-basis in the early stages of a project or when a facility has gone through major modifications. The barrier strategy establish in this phase must therefore always be open for adjustments later on. These adjustments are then often to a bigger degree based on the EPA, EPP along with other types of analyses, and the operational experiences.

A final challenge that should be linked to the identification of operational and organisational barriers is that the degree of details linked to the barrier requirements often varies between companies. A common critique is that the principles for barrier management previously have been vaguely described and that it has been difficult to implement the requirements given by the PSA in practise (Johansen & Rausand, 2015). The variation in detail was also brought forward by the PSA who talked about how they sometimes see important operational conditions that have been mapped, but the mapping has been done on an overriding level that it is hard for the person actually carrying out the action to fully understand it, and on the opposite side, mapping with such thorough description that every person knows exactly what to do and when to do it. However, as argued by P1 in section 5.5.1, a lot of specific details might result in a "loss of ownership" externally. As the PSA also emphasise that the procedures and challenges should be known across the organisations, both offshore and onshore, the overall goal should be to create an overview that the organisation as a whole can relate to. Another challenge linked to a high degree of details is that it might also lead to a loss of relevance, or that it becomes difficult to connect the different elements to the bigger picture.

This shows that the theoretical analyses and processes, to a large degree, are valuable for the operating companies when identifying the barriers that should be in place on a facility. It is important to emphasize that all companies include other analyses as well, but the QRA and EPA / EPP are both important tools in the mapping/design stage. In the operating phase, the QRA, due to its technical content, are less frequently used, but the EPA / EPP are continuously revised and updated to include and map the barriers. Can the companies know for certain that the right barriers have been identified? Probably to some extent, by basing them on the identified MAH. Nevertheless, finding the right level of details that should be included is more challenging, as neither the PSA nor the industry has found the right balance.

6.2. Secure that the identified barriers and associated roles and actions are understood and performed by personnel

Following Figure 4, the mapping and identification done in the pre-crisis phase should also create a foundation of instructions for relevant personnel to carry out the identified roles and actions needed in the realisation of different barrier functions in an emergency preparedness situation. According to relevant literature, it would be natural to implement the specific instructions in the EPP as this document should contain guidelines for how the emergency preparedness organisation should handle DSHA in an efficient and appropriate manner (Eriksen et al, 2021; Njå et al., 2020). As Eriksen et al. (2021) discusses, one way to make the relevant information easily accessible in an emergency preparedness situation is to divide the EPP into an administrative part and an operational part, where the latter can be used as a tool for guidance for the emergency preparedness organisation. However, when faced with a potential MAH, time is of the essence, and as several of the informants also mentioned, it is unlikely that a person with a specific role in an emergency preparedness organisation will have the time to look up his/her specific role in a plan before they act. Thus, the understanding of the barriers and associated roles and action must be established beforehand, which sheds a strong light on the importance of training and exercise.

There were no disagreements in the interviews – training and exercise is key in securing that the personnel have the necessary competence to carry out the roles needed in the various DSHAs. By keeping a strong link between the information stated in the EPP and the set-up of training and exercise, the relevant barriers, roles, and actions should be included in each scenario. As the PSA (2017b) stress that both the EPA/EPP and the barrier strategy need to be facility-specific (as the handling of various situations will depend on the facility-specific challenges linked to the situation) the relevant personnel should consequently have an understanding of the facility-specific challenges linked to the facility they work on. Two informants (P1 and P4) mentioned in the interview that the facility-specific challenges to a large degree is covered in the EPP which the personnel should be familiar with. Two other informants (P2 and P3) mentioned additional internal systems that contains (or will contain) a broader overview of the various challenges linked to different facilities and relevant information on how to handle these that could give better input to the set-up of training and exercises. Regardless of which system the companies choose to design their training and exercise around, the main goal should be that scenarios relevant for the verification of performance measures defined for each DSHA are chosen.

Another factor that should be considered when discussing the performance of roles and actions amongst personnel, is the availability of relevant personnel. Competence takes time to build, and training and exercises should be done regularly to be effective in ensuring the right competence and secure verification of performance requirements. It is no secret that the plunge in oil prices from 2014-2016 led to major downsizing, which consequently led to replacement of personnel and an extensive use of hired personnel with less competence (Aalberg et al., 2019). Even though the situation has turned, the PSA have issued several audit rapports with suggestions of improvements linked to both inadequate staffing and level of competence in recent years (PSA, n.d.,b), which indicates that some companies are lacking an overview of how important roles should be filled, and the competence needed to fill them. A solution to securing an overview of who should fill the role is mentioned by informant P1, who stated that the specific roles in an emergency preparedness organisation are only assigned to permanent personnel. The same personnel then also go through calendar-based training on an individual level as well as exercises with the emergency preparedness organisation. By including specific performance requirement to the different roles, the operators can further secure an overview of the competence that is needed. Consequently, this can help secure that the relevant competence needed to fulfil a role always is present amongst personnel. Furthermore, informant P2 stressed that only those with a specific role in an operational barrier element should be required to know the facility-specific challenges linked to the situations they are involved in. This narrows down who needs to know what and creates a clear foundation of securing that roles and actions are performed correctly.

Through the interviews, informant P2 also mentioned another area that is worth discussing, namely that "(…) *everyone cannot know everything, and sometimes people may train on what they call an operational barrier element, but they might not know exactly why they train on it. Their understanding of the situation will depend on [which story] the training is based on" (*section 5.4.1). This might portray a gap between the expectations the PSA have for competence and understanding of roles and the expectations the operators have for the personnel. This area can be discussed from both sides. When faced with an emergency that can develop into a MAH, the personnel should in many cases almost react on instinct to avert the situation from developing (i.e., pushing the right button to shut down a system, muster from one place to another, activate deluge etc.). However, if personnel are too focused on the specific role and action they should do, without understanding the situation facing them, they might also struggle to obtain a big overview and be able to think what might happen next. To be able to achieve a sufficient understanding of a situation, and to prepare for potential surprises, the knowledge needs to be internalised (Vinnem & Røed, 2021, p. 258). To give the different personnel an understanding of the same "story", it could be relevant to include so-called tabletop exercises. A tabletop exercise is often referred to as a "discussion exercise", which allows emergency preparedness organisations to practise the full activation of emergency response plans face-to-face within confined, controlled, and low-stress discussion scenarios (Roud et al., 2021, p. 172). Tabletop exercises are likely already combined with bigger training and exercise routines amongst operators, but this is just to emphasise that they possible could be used to a bigger extend to ensure a common understanding amongst relevant personnel. Additionally, it would allow for operators to push the different scenarios further and discuss how the emergency preparedness organisation would have to adapt. Finally, it is an effective way to uncover if personnel unexpectedly end up in situation where they have overlapping responsibilities.

It is thus possible to argue that the work of securing that the roles and actions are performed by personnel in an emergency preparedness organisation mainly is done though training and exercise. By basing the training and scenarios used in the exercises on the DSHA identified in the EPA, the relevant challenges should also be included. Furthermore, by connecting performance requirements to the various roles, the operators also gain an overview of relevant competence that need to be covered. Nevertheless, the content in the EPA and information regarding facility-specific challenges is largely based on the input-information included in the analyses. Therefore, the two next sections will take a step back to discuss if the information basis is solid enough.

6.3. To what extent current analyses and methodologies provide sufficient information about facility-specific challenge

Section 6.1 and 6.2 makes it apparent that the analyses and methods used in the industry to establish emergency preparedness and identify the various barrier elements have a solid link the theory presented in section 3. However, the theory gives little insight into the quality of the information derived from the multiple analyses. The audit reports from the PSA serve as solid proof that theories, regulations, standards and guidance on how various processes and analyses should be done not necessarily result in an outcome that is strong enough to identify all the emergency preparedness challenges that are hidden on offshore facilities. Not only because each facility will vary from each other, but also because each company has implemented the analyses and methods differently. It also emphasises the challenge of transferring theoretical analyses and processes to an operational stage. This is not to say that there is something fundamentally wrong with the analyses and methods, but on the other hand, it is hard to pinpoint exactly what is missing from the various companies to cover all grounds. The aforementioned conundrum might be the foundation for much of the frustration that has been expressed from the operators, where a shared critique has been that the principles are vaguely described and that it consequently is difficult to implement the theory and framework in practice (Johansen & Rausand, 2015).

By reviewing the interview and responses from the PSA, the overall conclusion would be that the analyses and methodologies to a large degree are designed to provide all the information that would be necessary to map the facility-specific challenges. However, by reviewing the theory and the interviews with the other companies, two challenges stand out as particularly relevant when it comes to discussing the degree to which facility-specific challenges are identified. First, a shared opinion amongst the informants were that the foundation which the analyses and methods are built on, in many cases risk analyses (e.g. QRAs), is highly technical. Moreover, QRAs are packed with information, and thus, knowing what type of information that is relevant for uncovering facility-specific challenges can be difficult. This was emphasised by informant P3 (section 5.3.2) who said that they have experienced, trough investigations and audits later on, that essential information regarding challenges might have been overlooked or not completely understood. This was also clearly illustrated in the example presented by informant P) in section 5.5.3. Furthermore, as mentioned by informant P6 (section 5.5.1), companies that delivers analyses services to the operating companies are fully dependent on the information brought forward by personnel through the interviews conducted before the analyses are made. Consequently, if the personnel omit important details that might not have been captured, the analysis will lack the same information when completed. This underlines the importance of continuously update the analyses and plans to make sure that they include the necessary and relevant information.

Second, as mentioned by informant P9 (in section 5.5.3) and informant P3 (in section 5.5.1), the analyses and methods used today are likely too generic to identify facility-specific challenges. This is, again, elaborated thought the technical content of the QRA aimed at technical elements. Much of the facility-specific challenges are linked to the operational and organisational elements. A hydrocarbon leak is a hydrocarbon leak on any facility, but measures to handle the incident varies from each facility. As stated by informant P2 (in section 5.1.2) and informant P6 (in section 5.3.2) the information regarding the facility-specific challenges and measures to handle these is mostly identified though workshops or work meetings that includes personnel with different backgrounds and roles. Thus, the identification of facility-specific challenges and the mapping of the necessary competence to handle these is to a large degree dependent on the already established knowledge and competence of the personnel involve.

Based on this, one can argue that it should be possible to establish the information regarding facility-specific challenges through the current analyses and methodologies used. However, it will to a large extend depend on how the different operating companies choose to adapt them to their facilities. The quality of the information included in the analyses, and consequently the result from the analyses, are dependent on the background knowledge and competence of those who give the input to the analyses. Moreover, the importance of including relevant personnel is highlighted, to ensure that the development of various analyses do not end up as a desk exercise for consultants onshore. This is also essential to include facility-specific information in the generic analyses and methods to ensure that the analyses are taken from a theoretical starting point, down to an operational level. Nevertheless, knowing the amount of information that should be included and the number of personnel that is needed to uncover this information is not a straightforward answer.

6.4. Adjustments in the current methodology that can be implemented to increase the focus on facility-specific competence

As the previous section discussed, there are certain challenges linked to identifying the facility-specific challenges and measures to handle these through the use of current analyses and methodologies. In order to better facilitate for an increased focus on facility-specific competence in current analyses and methodology, it is, based on section 6.1 - 6.3 and the conducted interviews, possible to argue that there should perhaps be devoted more focus to the input-data, rather than focusing on documenting the outcome of the method used. This is also based on observations from the PSA, who in section 5.5.4, emphasise that the input-data is something many companies struggle with. It is evident that several companies envision how the access to input-data can be improved through digitalisation. However, digitalisation might lead to a greater access to relevant information and data, but without the necessary competence to interpret the data, the data will be of little use. Informant P3 stressed this is section 5.5.4, when talking about that a higher amount of complex data from various sources can make it difficult for the relevant personnel to interpret the data. Thus, as argued by P2 in the same section, the focus should rather be put on the data already available for operators and making sure effective ways to use the data are established. This would indicate that more effort is put in the stage of "off-academizing" the input-data so that the information derived from it are easier to understand.

Another important point of improvement is highlighted by informant P8 in section 5.5.1, who brough forward that a lot of the establishment concerning barrier management is based on one event, namely hydrocarbon leaks. This is due to the QRA being mainly structured around the causes and consequences of events related to loss of containment and the level of impact it might have on people (Vamanu et al., 2016). There are however, as seen in Table 1, several other DSHA that are relevant, which then do not fit as well in the already developed standards and methodologies. An aim should therefore, according to informant P8, to make the standards and methodology 'scenario-free' to better apply them to various areas. A potential challenge with 'scenario-free' guidelines is that they might become even more generic, which already has been said to be a challenge as it is today.

A final area of improvement that the author sees as highly relevant, which also could benefit the industry greatly, is brought forward by informant P4 in section 5.5.1. Instead of learning from external rapports after an audit has been conducted by the PSA, the different operating companies could look at possibilities for merging the information they include in their analyses already at the early stages. This way, it would not be each company struggling to meet the requirements set by the PSA, but rather the industry as a whole attempting to find solutions that are possible to achieve. Of course, the operating companies are first and foremost competitors on the NCS, and this is not to suggests a 'everybody should be friends and help out'-approach, but as highlighted by both the PSA and the consultant company, it is never possible to map everything one hundred percent. Therefore, when the focus on facility-specific competence has been brought forward by the PSA as a pressing concern, the industry could benefit from cooperating on how to solve the challenges linked to it.

6.5. How to ensure that facility-specific competence is present in an emergency preparedness organisation

Based on the previous sections, it is evident that the challenge of ensuring that facility-specific competence present in an emergency preparedness organisation is far from an easy one to solve. This is mainly due to the functional framework that the challenge is identified through, the many analyses and processes that should be conducted to identify the relevant facility-challenges, the variations between the different companies and the division between the technical and operational. It is thus understandable that the industry might struggle to meet the requirements issued by the PSA. Nevertheless, some areas that stands out as important when trying to map the facility-specific challenges and associated competence are worth emphasising.

The mapping of facility-specific challenges and associated measures to handle them hinges on the accumulated knowledge and competence behind the information included in the analyses and methods used. When trying to solve this equation, two different perspectives can be applied. It is possible to view the challenge through 'the glass is half empty'-approach where the industry can say "we do not have the necessary information to identify all these challenges, how do we gain it?"; or, they can tackle it through a 'the glass is half full'-approach where the industry might say that "this is the information we have, how can we gain a better control over it and make it available?". This is not meant to sound like the industry is faced with one pessimistic and one optimistic approach, because both are relevant when studying ways in which the facility-specific competence can be mapped.

By applying the 'glass half empty' approach, ways of accessing more information are the primary focus. The industry is hopeful that future digitalisation can help them gain easier access to the relevant information and input data that are needed to map the various challenges and the associated operational and organisational measures. However, more information is not always better, as it will largely depend on the quality of the data available. Additionally, with new technology comes the need for new competence to handle the systems. And thus, the outcome of the analysis of data is then again dependent on the overall competence of those in charge. Nevertheless, if good ways of managing the new information can be established, there is no doubt that more and better data will have a significant impact of how the industry analyse and managed MAH. It can also provide a clearer and wider decision basis for how to handle different error, danger, and accident situations. Albeit being opportunities linked to the future, several companies are already trying to find more effective ways to access and understand the information needed, and the PSA are rooting them on. Still, the PSA also emphasise that many talks about these possibilities as something that is just around the corner, but in reality, they might have a long way to go. Thus, the primary focus should be to adapt a 'glass half full'-approach and find ways improve the current analyses and methods used in the industry.

When trying to view the challenge trough a 'glass half full'-approach, ways to better understand the already existing information are important to establish. It is furthermore essential to transfer the theoretical nature of the analyses, standards and methods over to information that is understandable to the personnel working on the facility. By focusing on how the industry today assess the different MAH, establish the emergency preparedness to handle the DSHA and map the different operational and organisational barriers and associated performance requirements, it is, based on the results from the interviews, possible to highlight four areas that can be seen as crucial in connecting the generic and technical base of the theory to the mapping of facility-specific challenges. Two of them already applied to the current methodologies are (1) to make sure that the relevant personnel are included in the establishment of the EPA and EPP, to uncover possible challenges that are relevant and specific for the operation of the facility, that are not covered by the technical elements in the QRA or more generic analyses, and (2) establish specific and concrete competence requirements for the identified roles related to each DSHA. The author would argue that these two areas already have gained a lot of attention in existing theory, especially when focused on what should be included in stage of mapping in the pre-crisis phase of emergency preparedness planning (Eriksen et al., 2021; Engen et al., 2016). These two points will of course not guarantee that all information is made available, but it provides a bridge between the generic and theoretical over to the more facility-specific conditions. Moreover, by establishing performance requirements for the organisational barrier elements and the necessary competence that is needed within every role, the operators can verify if personnel have the competence needed to perform the assigned roles. The two aforementioned points have been added to create a red line from the theoretical process of identifying MAH in the QRA to the establishment of training and exercise and are placed as number 2 and 3 in the figure below.

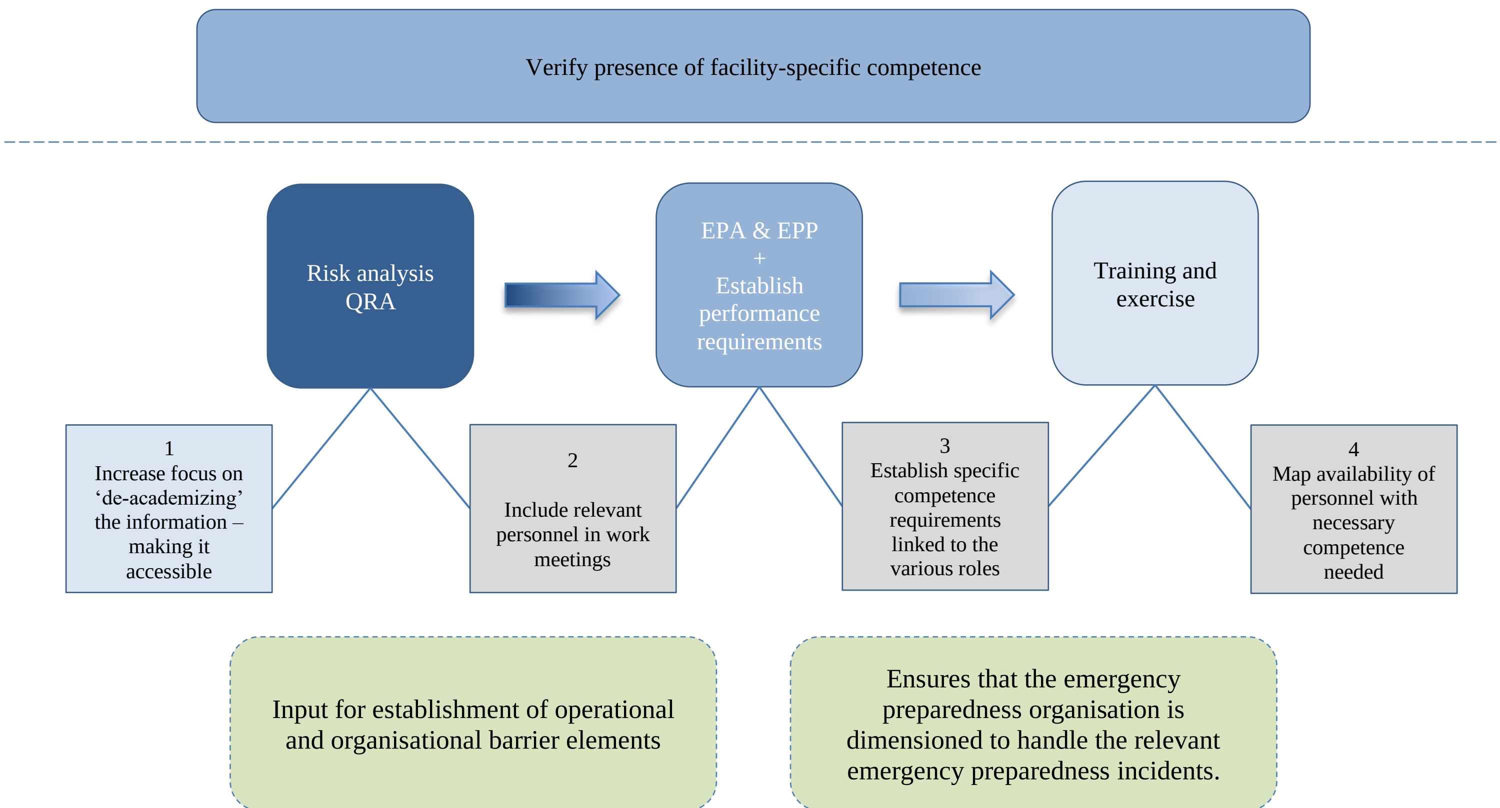

Figure 6 Extended version of the theoretical backdrop to better include facility-specific conditions

As seen in Figure 6, two additional points have been added. These two divert somewhat from the current processes and methodologies, but they are nevertheless two important areas that were brought forward by the different companies. The first one is to increase the focus on getting the available information in the QRA 'de-academized' to make it more understandable and accessible for the operational personnel. This would add to the information basis that the EPA and EPP build on. It would also give valuable input to the setup of training and exercise as it would be easier for the operating companies to include facility-specific conditions that might impact the development of different scenarios. Current theory relevant for emergency preparedness (and barrier management) has a starting point that to a large degree is set *after* identified risks have been mapped through different risk analyses. Thus, little attention is brought the amount and quality of the information that identification is built on, and the transfer of information between those how conduct the risk analyses and those who establish the emergency preparedness. The second point, added at the very end of the figure, is to create systems where operators can map the available competence at each facility. This would enable them to monitor the status of organisational barriers and identify gaps between the identified DSHA and the organisational measures needed in the realisation of various barrier functions. Monitoring different barriers is stressed as an important area by the PSA. However, how to monitor the necessary equipment and roles needed in an emergency preparedness situation falls outside the framework of current theory. The barrier memorandum (2017b) emphasises the importance and clearly states that operators should monitor the performance of various barriers. Mapping relevant competence available could therefore be one way to monitor organisational barriers. That being said, the man obstacle to successful identification of operational and organisation barrier elements, and the associated competence needed to perform them, is the availability and understanding of relevant information. Hence, an increased focus on enhancing the knowledge base will likely contribute to improve the overall quality for the rest of the process, and should thus, be the main priority.

With little experience from the industry itself, the author acknowledges that point 1 and 4 included in the concluding figure is likely harder to implement than how it has been presented. Therefore, it should be viewed as a trail of thought rather than pure recommendations for improvements. However, when attempting to discuss a topic that few have focused on earlier, there might be room for some challenging suggestions even though it might not be successful in practise. In the end: nothing ventured - nothing gained.

7. CONCLUSION

In an attempt to answer the research problem, "*How to ensure that facility-specific competence is present in an emergency preparedness organisation"* this study has utilized relevant theory related to emergency preparedness and semi-structured interviews to gain insight into a topic that few previously have explored. To create a better foundation to build the research problem on, a set of additional research questions were formulated*; How do the operators ensure that the right barriers have been identified?; How do the operators secure that the identified barriers and associated roles and actions are understood and performed by personnel?*; *To what extent do current analyses and methodologies provide sufficient information about facility-specific challenges?;* and*, What adjustments in the current methodology can be implemented to increase the focus on facility-specific competence?* The aim has been to unravel how operating companies secures that relevant information regarding facility-specific challenges and competence relevant to handle these are included in the establishment of the emergency preparedness organisation. Nevertheless, the responses from the interviews made it apparent that this is far from a straightforward answer.

Even though the analyses and methodologies presented in the theory to a large degree are used by the operating companies, various challenges have been identified. Two of the main concerns were linked to the access and understanding of relevant information and to the challenge of transferring the analyses and methodologies from a technical, generic level to an operational level. These to challenges are linked together as the findings suggest that the analyses *are* designed to uncover facility-specific challenges, but to which degree these are identified will largely depend on the input-data. In order to map the facility-specific competence, which serve as an important component of organisational barrier elements, operators are dependent on that the right information is included in the analyses.

Thus, the author concludes that the current theoretical processes and methodologies are designed to capture the various challenges on offshore facilities. However, how effective they are in identifying challenges linked to facility-specific conditions hinges on the accumulated knowledge and competence behind the information included in the analyses and methods used. Therefore, more attention should be paid to the information to which the analyses and processes are built on to make sure that the information already available are understood and accessible. Including the right information in the analyses and combining it with input from relevant personnel, the establishment of competence requirements, and potential ways of mapping the available competence will allow operators to make the analyses and plans facility-specific, and furthermore, ensure that right competence linked to facility-specific challenges is identified and present.

7.1. Limitations and further research

Indeed, limitations must be stated when discussing analyses and methodologies used in the offshore oil and gas industry. This study has been limited to primarily focus on the QRA and EPA/EPP as analyses to identify the facility specific challenges and the associated operational and organisational barrier elements needed in handling the different DSHA. They were chosen on the background that they are frequently used in the industry. However, in a typical oil and gas company, analysing and understanding the risk picture is not covered by one single activity, but by different types of analyses and processes. Thus, studies focusing on other types of analyses should be conducted to contribute to the overall understanding of how the work of identifying facility-specific challenges are carried out. Furthermore, interesting studies could also be conducted based on either point 1 or 4 in Figure 6, to see if the trail of thought presented in this study can be further built on.

8. REFERENCES

Aalberg, A. L., Bye, R. J., Kvalheim, A., Vinnem, J. E, Furland, G., & Hauland, G. (2017). *Feltstudie – Oppfatninger Om Endringer Og Sikkerhetsimplikasjoner I Petroleumsindustrien*. Available from: https://www.safetec.no/wp-content/uploads/2019/09/ST-13497-2-Feltstudie-oppfatninger-om-endringer-og-sikkerthetsimplikasjoner-i-petroleumsindustrien-onshore.pdf

Andersen, S. S. (2006). Aktiv informantintervjuing. *Norsk Statsvitenskapelig Tidsskrift 22*, 278-298

Aven, T. (2020). *The Science of Risk Analysis* (1st ed). London: Routledge.

Aven, T., Renn, O. (2009). On risk defined as an event where the outcome is uncertain. *Journal of Risk Research*, *12*(1), 1–11.

Aven, T., Renn, O., & Rosa, E. A. (2011). On the ontological status of the concept of risk. *Safety Science*, *49*(8-9), 1074-1079.

Aven, T., Boyesen, M., Njå, O., Olsen, K. H., & Sandve, K. (2004). *Samfunnssikkerhet*. Oslo: Universitetsforlaget.

Blaikie, N. (2010). *Designing Social Research* (2nd ed.). Cambridge: Polity Press.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.

Danermark, B., Ekström, M., Jakobsen, L., & Karlsson, J. C. (2002). *Explaining Society: Critical realism in the social sciences*. London: Routledge

Ditchburn, S., & David, D. (2006). Understanding major accident hazard management-the more you know, the more you know you don't know. In *Institution of Chemical Engineers Symposium Series* 151. Rugby: Institution of Chemical Engineers. Available from: https://www.icheme.org/media/9846/xix-paper-59.pdf

Engen, O. A. H., Kruke, B. I., Lindøe, P. H., Olsen, K. H., Olsen, O. E., Pettersen, K. A. (2016). *Perspektiver på samfunnssikkerhet*. Oslo: Cappelen Damm.

Eriksen, J., Rake, E. L., Sommer, M. (2021). *Beredskapsanalyse* (1st ed.). Oslo: Cappellen Damm Akademiske.

Fjaeran, L., & Aven, T. (2021a). Creating conditions for critical trust–How an uncertainty-based risk perspective relates to dimensions and types of trust. *Safety Science*, *133*, 105008.

Fjaeran, L., & Aven, T. (2021b). Making visible the less visible–how the use of an uncertainty-based risk perspective affects risk attenuation and risk amplification. *Journal of Risk Research*, *24*(6), 673-691.

Gillespie, D. F., & Streeter, C. L. (1987). Conceptualizating and measuring disaster preparedness. *International Journal of Mass Emergencies and Disasters*, *5*(2), 155-176.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report*, *8*(4), 597-607.

Halvorsen, K. (2008). *Å forske på samfunnet: en innføring i samfunnsvitenskapelig metode* (5th ed.). Oslo: Cappelen Damm.

Hauge, S., & Øien, K. (2016). Guidance for barrier management in the petroleum industry. *SINTEF report A*, *27623*.

ISO. (2021). *Standards.* Available from*:* https://www.iso.org/standards.html

Iversen, A. B. (2011). Kvalitative og kvantitative metoder–et kontinuum? *Sosiologisk tidsskrift*, *19*(02), 175-183.

Jacobsen, D. I. (2005). *Hvordan gjennomføre undersøkelser? : innføring i samfunnsvitenskapelig metode* (2. utg., p. 400). Høyskoleforl.

Jennings, M. (2020). The oil and gas industry, the competence assessment of Offshore Installation Managers (OIMs) and Control Room Operators (CROs) in emergency response, and the lack of effective assessment of underpinning technical knowledge and understanding. *Journal of Loss Prevention in the Process Industries*, *65*, 104090.

Jennings, M. (2019). The oil and gas industry, the Offshore Installation Manager (OIM) and the management of emergencies-Changes necessary to achieve effective competence assessment of OIMs in controlling emergencies. *Journal of Loss Prevention in the Process Industries*, *59*, 1-13.

Jennings, M. (2017). The Oil and Gas Industry, the Offshore Installation Manager (OIM), and the management of emergencies–Who is accountable for OIM competence?. *Journal of Loss Prevention in the Process Industries*, *50*, 131-141.

Jennings, M. (2016). Potential barriers to the competence assessment of Offshore Installation Managers: A hermeneutic perspective. *Journal of Loss Prevention in the Process Industries*, *44*, 132-142.

Johansen, I. L., & Rausand, M. (2015). Barrier management in the offshore oil and gas industry. *Journal of Loss Prevention in the Process Industries*, *34*, 49-55.

Jonassen, Ø., Sjølie, E. (2016). Barrier management in operation for the rig industry–a joint industry Project. Paper presented at the *Offshore Technology Conference Asia*. Available from: https://doi.org/10.4043/26819-MS

Jones, A., Joyce, A., Yan, H., Vilas, E. F., Potts, S. (2017). *Using Quantified Risk Assessment (QRA) in Feasibility Design.* https://www.icheme.org/media/15465/paper-15.pdf

Kaplan, S., & Garrick, B. J. (1981). On the quantitative definition of risk. *Risk Analysis*, *1*(1), 11-27.

Kirschenbaum, A. (2002). Disaster preparedness: A conceptual and empirical reevaluation. *International Journal of Mass Emergencies and Disasters*, *20*(1), 5-28.

Kruke, B. I., & Auestad, A. C. (2021). Emergency preparedness and rescue in Arctic waters. *Safety Science*, *136*, 105163.

Kvale, S., & Brinkmann, S. (2015). *Det kvalitative forskningsintervjuet* (3. ed.). Oslo: Gyldendal Norsk Forlag.

Kvernmo, G. (2005). Intervju som metode - barn/unge som informanter. Studenten som forsker i utdanning og yrke. I I. R. Knudsen (Ed.), *Vitenskapelig tenkning og metodebruk* (ss. 66-92). Kjeller: Høgskolen i Akershus

Lauridsen, O., Lootz, E., Husebo, T., & Ersdal, G. (2016). Barrier management and the interaction between technical, operational and organisational barrier elements. Paper presented at *SPE International Conference and Exhibition on Health, Safety, Security, Environment, and Social Responsibility*. OnePetro. Doi: 10.2118/179364-MS

Lowrance, W.W. (1976). *Of acceptable risk: Science and the determination of safety*. Burlington: William Kaufmann

Lupton. (2013). *Risk* (2nd ed.). Routledge.

McLeod, R. W. (2017). Human factors in barrier management: Hard truths and challenges. *Process Safety and Environmental Protection*, *110*, 31-42

Milch, V., & Laumann, K. (2019). The influence of interorganizational factors on offshore incidents in the Norwegian petroleum industry: Challenges and future directions. *Reliability Engineering & System Safety*, *181*, 84-96.

Njå, O., Sommer, M., Rake, E. L., & Braut, G. S. (2020). *Samfunnssikkerhet: analyse, styring og evaluering*. Oslo: Universitetsforlaget.

Noble, H., & Smith, J. (2015). Issues of validity and reliability in qualitative research. *Evidence-based Nursing*, *18*(2), 34-35.

Norazahar, N., Smith, J., Khan, F., & Veitch, B. (2018). The use of a virtual environment in managing risks associated with human responses in emergency situations on offshore installations. *Ocean Engineering*, *147*, 621-628.

Norwegian Petroleum. (2021). *Petroleum Related Research and Development.* Available from: https://www.norskpetroleum.no/en/environment-and-technology/petroleum-related-research-and-development/#research-and-technology

NORSOK (2010). *Z-013 Risk and emergency preparedness assessment.* Oslo: Norwegian Technology Standard Institution.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Sage Publications

Perry, R. W., & Lindell, M. K. (2003). Preparedness for emergency response: guidelines for the emergency planning process. *Disasters*, *27*(4), 336-350.

Proactima. (n.d). *Hazard identification (HAZID).* https://proactima.com/counsel-and-analysis/analysis/hazard-identification-hazid-2/?lang=en

Proactima. (2021). *Quantitative Risk Analysis (QRA).* Available from: https://proactima.com/counsel-and-analysis/analysis/quantitative-risk-analysis-qra-2/?lang=en

PSA. (n.d. a). *Role and area of responsibility.* Available from: https://www.ptil.no/en/about-us/role-and-area-of-responsibility/

PSA. (n.d. b). Available from: *Search Audits and Investigation Rapports. https://www.ptil.no/en/search-audit-reports/?q=staffing*

PSA. (2022). *HOVEDRAPPORT 2021 UTVIKLINGSTREKK NORSK SOKKEL - Risikonivå i norsk petroleumsvirksomhet.* Available from: https://www.ptil.no/contentassets/ef05af52c13347d2aba7ceca1a42c137/rnnp-2021-hovedrapport-31.3.pdf

PSA. (2020). *HOVEDRAPPORT 2020 UTVIKLINGSTREKK NORSK SOKKEL - Risikonivå i norsk petroleumsvirksomhet.* Available from:
https://www.ptil.no/contentassets/94c4db2cb1d04520b5d50a05bc0961f9/rnnp-2020-sokkelrapport-rev2.pdf

PSA. (2018). *The Management Regulations §9*. Available from: https://www.ptil.no/en/regulations/all-acts/the-management-regulations3/III/9/

PSA. (2017a). *Sikkerhet og ansvar – Forstå det Norske regimet.* Available from: https://www.ptil.no/contentassets/0079bf5eb8824beb969fd0f217f395b7/sikkerhet-og-ansvar.pdf

PSA. (2017b). *Principles for barrier management in the petroleum industry - Barrier Memorandum 2017.* Available from: https://www.ptil.no/contentassets/43fc402b97e64a7cbabdf91c64b349cb/barriers-memorandum-2017-eng.pdf

PSA. (2013). *Prinsipper for barrierestyring i petroleumsvirksomheten.* Available from: https://www.ptil.no/contentassets/11851dc03a84473e8299a2d80e656356/prinsipper-for-barrierestyring-i-petroleumsvirksomheten_2013.pdf

PSA. (2006). *Utvikling i riskonivå - norsk sokkel.* Available from: https://www.ptil.no/contentassets/7a48e82b5f5d430bb159e60431691ab3/fase6rapporttotal1.pdf

Reason, J. (2016). *Managing the risks of organizational accidents*. London: Routledge.

Renn, O. (2008). *Risk Governance: coping with uncertainty in a complex world.* London: Earthscan.

Roud, E., Gausdal, A. H., Asgary, A., & Carlström, E. (2021). Outcome of collaborative emergency exercises: Differences between full-scale and tabletop exercises. *Journal of Contingencies and Crisis Management*, *29*(2), 170-184.

Røyksund, M., & Engen, O. A. (2020). Making sense of a new risk concept in the Norwegian petroleum regulations. *Safety Science*, *124*, 104612.

Shippmann, J. S., Ash, R. A., Batjtsta, M., Carr, L., Eyde, L. D., Hesketh, B., ... & Sanchez, J. I. (2000). The practice of competency modeling. *Personnel Psychology*, *53*(3), 703-740.

Skjerve, A. B., Albrechtsen, E., & Tveiten, C. K. (2008). Defined situations of hazard and accident related to integrated operations on the Norwegian continental shelf. *SINTEF Report A*, *9123*, 2008.

Sklet, S. (2006a). *Safety Barriers on Oil and Gas Platforms: Means to Prevent Hydrocarbon Releases* [PhD, NTNU]. Available from: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/241291/122483_FULLTEXT01.pdf?sequence=1

Sklet, S. (2006b). Safety barriers: Definition, classification, and performance. *Journal of Loss Prevention in the Process Industries*, *19*(5), 494-506.

Sklet, S. (2004). Comparison of some selected methods for accident investigation. *Journal of Hazardous Materials*, *111*(1-3), 29-37.

Skogdalen, J. E. (2011). *Risk management in the oil and gas industry: Integration of human, organisational and technical factors.* [Phd thesis, University of Stavanger]. Available from: https://uis.brage.unit.no/uis-xmlui/bitstream/handle/11250/182335/Skogdalen%2c%20Jon%20Espen.pdf?sequence=1&isAllowed=y

Skogdalen, J. E., & Vinnem, J. E. (2011). Quantitative risk analysis offshore—human and organizational factors. *Reliability Engineering & System Safety*, *96*(4), 468-479.

Skogdalen, J. E., & Vinnem, J. E. (2012). Combining precursor incidents investigations and QRA in oil and gas industry. *Reliability Engineering & System Safety*, *101*, 48-58.

Standards Norway. (2021, December 17). *NORSOK Standards*. https://www.standard.no/en/sectors/energi-og-klima/petroleum/norsok-standards/#.YhIYlljMIWq

Step Change in Safety. (n.d). *Major Accident Hazard Understanding.* Available from: https://www.stepchangeinsafety.net/workgroups/major-accident-hazard

St. Pierre, E. A., & Jackson, A. Y. (2014). Qualitative data analysis after coding. *Qualitative Inquiry*, *20*(6), 715-719.

Staupe-Delgado, R., & Kruke, B. I. (2018). Preparedness: Unpacking and clarifying the concept. *Journal of Contingencies and Crisis Management*, *26*(2), 212-224.

Thomas, D. R. (2006). A general inductive approach for analyzing qualitative evaluation data. American journal of evaluation, 27(2), 237-246.

Tveiten, C. K., Albrechtsen, E., Wærø, I., & Wahl, A. M. (2012). Building resilience into emergency management. *Safety Science*, *50*(10), 1960-1966.

Vamanu, B., Necci, A., Tarantola, S., & Krausmann, E. (2016). *Offshore Risk Assessment. Methods and Tools-An Overview of Methods and Tools*. JRC Technical Reports. Available from: https://euoag.jrc.ec.europa.eu/vicos/uploads/2018/10/03/Offshore%20Risk%20Assessment.Methods%20and%20tools.pdf

Vinnem, J. E. (2010). Risk indicators for major hazards on offshore installations. *Safety Science*, *48*(6), 770-787.

Vinnem, J-E., & Røed, W. (2020). *Offshore Risk assessment Vol. 2- Principles, Modelling and Applications of QRA Studies.* (4th edt.) Springer: London.

Willis, H. (2007). Guiding Resource Allocations Based on Terrorism Risk. *Risk Analysis, 27*(3), 597-606.

Woodcock, B., & Toy, K. (2011). Improving situational awareness through the design of offshore installations. *Journal of Loss Prevention in the Process Industries*, *24*(6), 847-851.

9. ATTACHMENTS

9.1. Interview guide

Barriers:

1. How do you define operational and organisational barriers?

2. To what extent do you use QRA and / or other risk assessments to identify operational and organisational (barriers) measures to be able to handle a hazard and accident event?
   a. Do you use the same approach both in new construction projects and in operation?

3. How do you ensure consistency between operational and organisational measures, and actions in a hazard and accident event?

4. How to ensure that relevant performance requirements include facility-specific emergency preparedness challenges and measures to deal with these?

Emergency preparedness:

5. How do you include operational and organisational barriers in the design of the EPA?

6. To what extent is the focus on facility-specific challenges in establishing the EPA? How are the emergency preparedness challenges identified?

7. How to ensure that personnel have knowledge of facility-specific challenges and operational and organisational barriers?

8. How to ensure that personnel have relevant competence and training to handle facility-specific errors, hazards, and accident situations?

General / future:

9. Do you see points for improvement in the current methodology for increasing the focus on facility-specific challenges and measures to deal with these?
   a. To which degree do current analyses provide a sufficient basis for identifying challenges and measures?

10. Do you see a challenge in that too much focus on facility-specific challenges and measures can cause you to lose focus on the basic skills to be able to handle an error, danger and accident situation?

11. How do you think digitization and development of barrier status panel will be able to influence the way this is done in the future? What opportunities / challenges do you see?