

Understanding and managing the non-technical elements of the major accident barrier model; perspectives from regulation of Human Factors in the North Sea Oil and Gas industry.

1. Abstract

The layers of protection and safety barrier concept is established in the North Sea offshore Oil and Gas industry and this is generally reflected in the presentation of major hazard analyses that form part of Safety Cases in the UK offshore safety regime. The difference between "hard" engineered barrier elements, known as technical barriers, and non-technical, human-oriented elements is also reflected in the established plant / process / people concept. On the non-technical side, the 'process' or 'operational' element appears to be the least firmly established and integrated into normal operations. This element covers the safety critical tasks performed in order for the barrier function to work (HAVTIL, 2017). Key challenges include capturing and the managing the difference between task-related information in the form of written procedures and actual behaviour and the Performance Influencing Factors (PIFs) that can affect it. Further, the development of performance requirements or standards for operational barrier elements has generally not matched how equivalent requirements/standards have been established and operationalised for technical and organisational barrier elements. Despite the stated inclusion of non-technical elements in their barrier models, inspection has revealed that many UK offshore duty holders and organisations do not have a mature method for working with the operational barrier element and have not developed performance standards for critical tasks. Safety Critical Task Analysis (SCTA) is an established methodology in use offshore and in onshore high-hazard industries, though the maturity of the process varies between offshore duty holders. SCTA is task-centric and helps to identify how human failure might occur in critical task steps and where additional risk controls are required. Understanding critical tasks through the SCTA process provides a robust basis for developing performance standards and hence improving the barrier management system, but this link is under-recognised and hence the two activities have suffered from siloing. Alongside improved efficiency, better alignment between the operational barrier element management and SCTA supports the requirements of Principle 8 of the Assessment Principles for Offshore Safety Cases (APOSC) that covers human reliability in safety critical tasks. This paper will be of interest to Hazards delegates as it continues to explore the safety barrier topic that has featured at previous Hazards conferences, such as Joseph et al (2021), Bucelli et al (2017) and Pitblado et al (2016), but introduces a new angle through reference to SCTA. It also provides delegates with some real-world insights from a regulator's perspective, where other more recent papers on safety barriers such as Shuaiqi et al (2022) have focused on academic developments. Benefits of this paper to Hazards delegates include improved insight into the offshore safety regulator's perspective on non-technical barrier management and how this relates to compliance and potential enforcement. There is also a potential efficiency gain for delegates whose organisations manage a safety barrier system and have either established or are in the process of establishing a SCTA programme.

2. Abstract summary

The safety barrier concept is established in the North Sea offshore Oil and Gas industry, with historical focus on engineered, technical elements. The concept also incorporates non-

technical (‘people’ and ‘process’) elements that support barrier function. Understanding and analysing safety critical tasks performed for the barrier function to work – the ‘process’ or ‘operational’ element – and developing performance standards for them is an area of relative weakness that has been observed through regulatory activity. Safety Critical Task Analysis provides a structured methodology to support improvement in this area, which in turn supports the greater incorporation of human factors in major accident risk management.

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4. Paper

Title

Understanding and managing the non-technical elements of the major accident barrier model; perspectives from regulation of Human Factors in the North Sea Oil and Gas industry.

Introduction

The layers of protection and safety barrier concept to prevent the initiation and escalation of a Major Accident Hazard (MAH) is established in the North Sea offshore Oil and Gas industry. The principle of the barrier model is that measures can be designed and put in place to provide defence in depth against the initiation of an accident or the development and escalation of the accident and the degree of damage caused (Abia et al, 2019). The model is also commonly referred to as the "Swiss Cheese" model (after Reason, 1997), since weaknesses in successive barriers behave conceptually like holes in slices of Swiss cheese (albeit holes that may come and go, shift around and change size through time). If holes in successive layers of protection align, the risk of accidents increases.

The barrier concept and barrier model is generally reflected in the presentation of major hazard analyses that form part of Safety Cases in the UK offshore safety regime. These analyses are often presented and referred to as "Bow Tie" analyses due to the visual representation of the barrier elements on either side of a major accident scenario (otherwise known as a 'top event'). The analyses describe the barrier elements in place for a series of major accident scenarios that the duty holder considers may potentially affect their asset. Levels of Protection Analysis (LOPA) is another established technique used in the industry for analysing and assessing the robustness of safety barriers.

Technical and non-technical barrier elements

A barrier may consist of several elements that, together, realise the barrier's function. Barrier elements may be subdivided into technical and non-technical elements. The technical elements are engineered, technical systems and equipment. These are the "hard" barrier elements that support primary containment of hydrocarbons, instrumented monitoring and detection systems, shutdown systems and deluge systems. Following the definition described in Sklet (2006) and later by the Norwegian Ocean Industry Authority (HAVTIL, formerly the Petroleum Safety Authority) in 2017, the non-technical elements may be subdivided into organisational and operational elements. The organisational element includes personnel with defined roles, functions or competence that are specific to the barrier function. The actions or activities that personnel must perform to realise the barrier function are the operational barrier elements. A trained control room operator who must follow a defined sequence of actions in response to a vessel passing within the 500m zone of an offshore installation is an example of these two types of non-technical elements in action. Figure 1 provides an illustration of the three barrier elements in relation to active fire protection on an offshore installation. The same tripartite subdivision of barrier elements is also recognised within process safety management and offshore drilling as the Plant (technical), People (organisational) and Process (operational) elements.

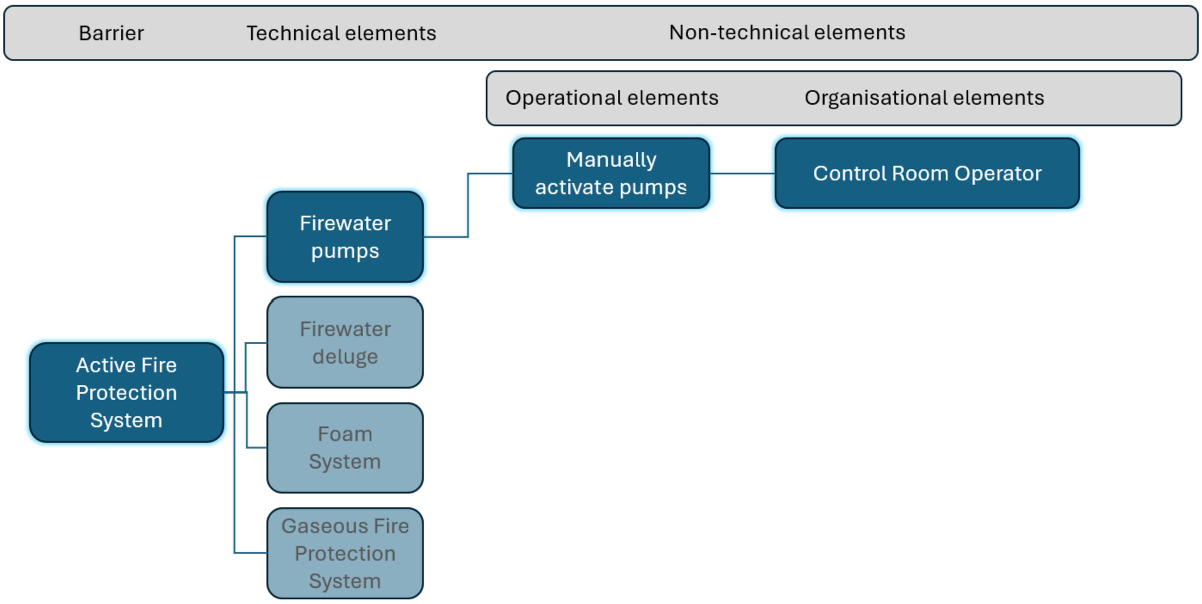

Figure 1. Simple illustration of technical, operational and organisational elements related to the active fire protection barrier on an offshore installation.

Performance Standards

By their very nature as protective measures against major accidents, including where other safety arrangements have failed, barriers must function as designed and be reliable. Key to barrier management is the concept of the performance standard. Performance standards specify how the barrier element must work, and the level of performance required to realise its function in response to accident scenarios. A more detailed definition is provided in the Approved Code of Practice for the Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995 (HSE, 2016). The defines performance standards as: *statements which can be expressed in qualitative or quantitative terms, of the performance required of a system, item of equipment, person or procedure, used as the basis for managing a hazard (e.g. planning, measuring, control or audit) throughout the life cycle of the installation.*

Without a performance standard, the credibility of a barrier element is diminished, and it may instead be more of a safeguard in practice. In the offshore industry, emphasis has historically been placed on technical barrier elements (HAVTIL 2017) and their associated performance standards. This reflects the importance or expected strength of barrier elements (CIEHF 2016) whereby engineered barrier elements rank highest, not least because they may function independently of human action and hence be less vulnerable to variance or failure in human performance. Similarly, technical systems and equipment lend themselves well to the development of performance standards that feature activation times, flow rates and similarly measurable and verifiable parameters. For organisational elements, the need for performance standards is helped by the role descriptions and competence requirements set out in an organisation's competence management system (CMS), though these may not be consistently acknowledged as being a barrier element. The CIEHF White Paper *Human Factors in Barrier Management* (2016) concluded that human performance to realise a barrier function (i.e. the operational element) was frequently identified in Bow Tie analyses in the high hazard process industries, yet the level of human performance (i.e. the performance standard) was generally not specified.

Regulatory insights from the North Sea offshore industry

The topic of safety barriers and barrier management has featured at previous IChemE Hazards conferences with insights from industry and academia provided variously by Joseph et al (2021), Bucelli et al (2017) and Pitblado et al (2016). Shuaiqi et al (2022) provides a potted history of the topic and focuses on academic developments in barrier management. The Health and Safety Executive Energy Division regulates offshore health and safety in the UK. This includes the investigation of accidents offshore, inspection and acceptance of operational safety cases for offshore installations and offshore inspections. Through these activities over the following issues related to non-technical barrier management have been observed:

- The focus of barrier management offshore principally remains on the technical elements. Technical barrier elements, also commonly referred to as Safety and Environmentally Critical Elements (SECEs) typically have performance standards associated with them and the arrangements for conducting assurance activities related to technical barrier elements and their performance standards are generally mature.

- Management of organisational elements tends to occupy second place after the technical elements, with acknowledgement of barrier-related roles and associated arrangements for competence attainment and competence management – typically via the duty holder's competence management system. Adequacy of staffing for critical roles is commonly included in barrier health monitoring and may be subject to the operational risk assessment (ORA) process for continuing operations with impaired barrier elements. However, the concept of performance standards for organisational/people elements is commonly not formalised in duty holders' management systems and understanding of the role of organisational elements in the barrier management system tends to be restricted to management roles.

- Operational barrier elements appear to be less well understood, and this is reflected in a lack of acknowledgement of their management in safety cases, and a general lack of performance standards associated with barrier-related tasks. Crucially, most duty holder management systems do not include information on how performance standards for operational elements should be designed, what criteria to include, or how assurance activities should be conducted. Most duty holders identify certain procedures as safety critical, but these are rarely linked to the concept of a barrier-related performance standard. Human error is frequently cited as a threat in major hazard analyses presented in safety cases, as described in McCleod (2017), but further detail on how it is managed or mitigated in relation to specific barrier-related activities is not usually covered.

- A small number of UK offshore duty holders have acknowledged operational barrier elements as forming part of their barrier model. This includes duty holders who conduct or have conducted operations in Norway where technical, organisational and operational barrier elements are referred to in Regulation 5 of the Management Regulations for the Petroleum Industry, 2011. The offshore drilling industry also makes common use of the plant/people/process concept within barrier management. However, inspection has revealed that the arrangements for managing operational elements and their incorporation in barrier health monitoring and assurance activities are underdeveloped.

- The regulatory arrangements for addressing non-technical barrier management in the UK offshore industry require greater clarity, including through guidance for topic-based inspection. There has not been a consistent approach to addressing non-technical barrier management, and instead organisational and operational elements have been approached in terms of staffing and competence arrangements and management of safety critical tasks respectively. The role and design of performance standards for non-technical, and particularly operational barrier elements have not been addressed via a structured inspection approach.

As a general summary, where non-technical barrier elements are acknowledged it tends to be at high level, but considerable gaps and shortcomings begin to emerge when progressing into the more detailed aspects of their management, particularly in relation to understanding the role of performance standards and how to develop them.

An analysis of HAVTIL inspection reports from the Norwegian sector on the topic of barrier management, covering both operating companies and drilling contractors, revealed similarities with the observations above. Common themes arising from the inspection reports were:

- Poor integration of operational and organisational barrier elements in risk management activities compared with technical (engineered) elements
- Inadequate work related to developing performance standards for operational barrier elements, where performance standards were either not developed or insufficient progress had been made with developing them
- Insufficient provision of training and competence-related issues that undermined the robustness of the organisational barrier elements.

This indicates that within a regulatory framework where technical and non-technical barrier elements are specified through regulations for the oil and gas industry, and where the state of knowledge in both the industry and regulator is likely more mature, gaps remain. This possibly points to a problem with methodology, application and integration related to non-technical elements.

Establishing Performance Standards for non-technical barrier elements

The CIEHF White Paper *Human Factors in Barrier Management* (2016) provides extensive guidance and examples for developing performance standards for non-technical barrier elements. In this guidance the organisational and operational elements are combined under the banner “human performance standard”. CIEHF present six key characteristics for a human performance standard:

1. The (human) performance should be specific to the threat and the situation where the barrier function is needed. This includes defining the goal of the performance.
2. The performance standard should clearly define who is expected to be involved with delivering the required performance. This includes detecting that the barrier function is needed, who decides what should be done, who takes action the implement the function and who is relied upon to support the barrier.
3. The performance standard should identify the level of competence required by each individual involved.
4. The performance standard sets out an appropriate expectation for timing of performance. The timing for initiation of the human performance and the time to completion should be appropriate to the timescale of the threat/hazard.
5. The standard of successful performance should be clearly defined, including tolerance limits for acceptable performance.
6. The performance standard should document how operations around the barrier will be conducted that are especially critical to performing its function.

The White Paper also advises that human barrier elements should be subject to Critical Task Analysis to support development of performance standards, so that potential errors and their causes are sufficiently mitigated against. However, it stops short of providing further information about (Safety) Critical Task Analysis and otherwise does not explore the alignment of task analysis with performance standard development in further depth. Øie (2014) also explored using task analysis to support the development of performance standards for operational barrier elements, including identifying factors that could negatively affect performance.

Safety Critical Task Analysis

Safety Critical Task Analysis (SCTA) is a methodology that seeks to improve mitigation against the human contribution to MAH risk. SCTA is human and task-centric, and hence provides a balance to more hardware focused risk analysis methodologies (HSE 1999). SCTA involves identifying and prioritising tasks that, if performed incorrectly, could contribute to the initiation or escalation of a major accident. These tasks are then subject to task analysis whereby individual task steps are defined. This is followed by detailed human reliability analysis (HRA) where, for each task step, likely human errors and performance influencing factors (PIFs) are identified and the adequacy of control measures each task step is examined. The process recommends involving frontline personnel and drawing on their hands-on knowledge and experience of tasks and credible errors and PIFs associated with them. SCTA is supported by guidance published by the Health and Safety Executive (1999), the Energy Institute (2020), CIEHF (2023) and Step Change in Safety (2025 – publication pending). This guidance generally makes limited reference to non-technical barrier management and performance standards, though it might be anticipated that many safety critical tasks might be associated with a barrier. SCTA is commonly linked to procedures, both as a methodology to support procedure development and for challenging the adequacy of existing procedures. Procedures from a duty holder’s management system are commonly used to support the creation of an inventory of safety critical tasks in the initial phase of the SCTA process. Identified improvements to procedures are a common output of Human Reliability Analyses.

SCTA is generally acknowledged within the UK offshore industry as a key Human Factors risk management activity. Establishment of an SCTA programme helps to satisfy Principle 8 of the Assessment Principles for Offshore Safety Cases (APOSC) that covers human reliability in safety critical tasks. However, regulatory inspections have revealed varying degrees of progress and maturity with the process between duty holders, including both operating companies and drilling contractors. Common issues arising from inspection activity include sufficient scope of identification of safety critical tasks, lack of timely progress with the completion of the detailed task and HRA components and insufficient internal competence and capability to drive the SCTA programme. More recently, a small number of duty holders have conceptually linked SCTA to barrier management and the development of performance standards, though progress with operational delivery has been limited. SCTA programmes have tended to exist aside and separately from barrier management activities, and in many cases are facilitated as a distinct programme of work by specialist Human Factors consultants on behalf of the duty holder. This can act as a barrier to both ownership and deeper integration of the process with other risk management activities within an organisation.

Aligning performance standards for non-technical barrier elements with safety critical task analysis

Figure 2 builds on information presented in CIEHF (2016) by incorporating key steps from the SCTA process as set out in HSE (1999), Energy Institute (2020) and CIEHF (2023). Specifically, Figure 2 shows how the more detailed steps of task and human error analysis in the SCTA process can help to support the required characteristics of a human performance standard. It is assumed that within the barrier model the main hazards and the operational barrier elements (i.e. the critical tasks) would already be known, but if not then steps 1 and 2 of the SCTA process could also be used to support their identification. It is anticipated that tasks that constitute a barrier element would be included in the scope of critical tasks in the SCTA programme, though this is dependent to some extent on the degree to which operational elements in the barrier model are expressed as tasks (Energy Institute 2020).

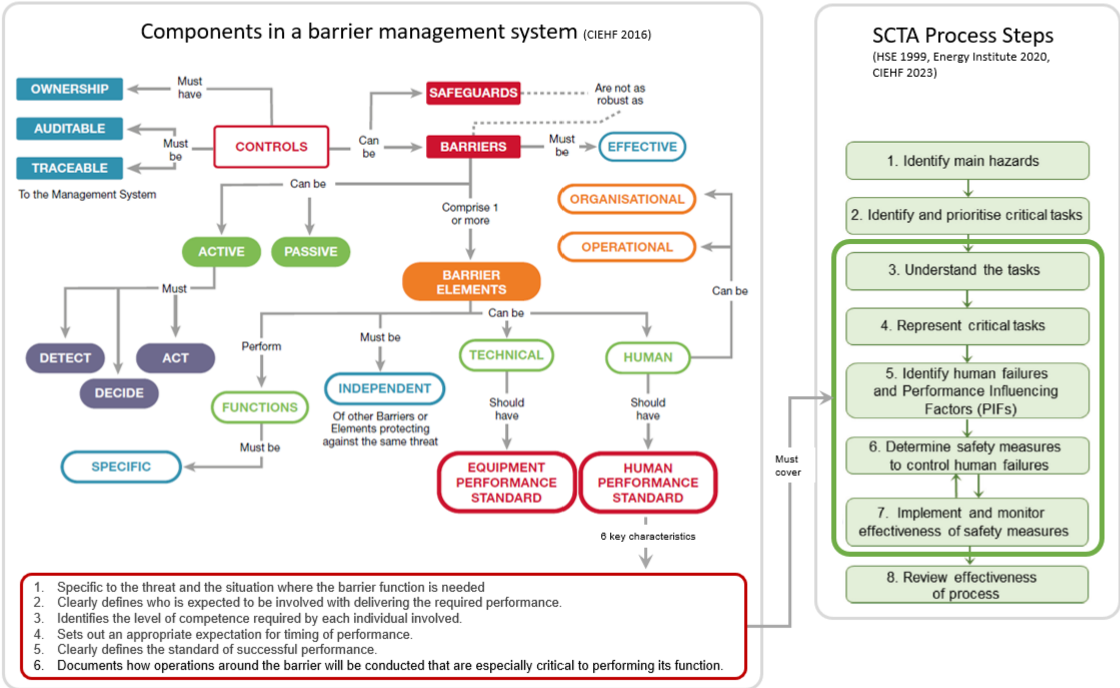

Figure 2. Illustration of the link between establishment of performance standards for non-technical barrier elements and selected steps of the safety critical task analysis process.

If a duty holder has successfully progressed through the stages of safety critical task analysis for a particular task, information related to the 6 performance standard characteristics set out in CIEHF (2016) should be at least better known if not fully understood. To recap, this would include:

1. A clear(er) definition of the goal of the performance related to a threat / situation where a barrier function is needed.
2. A clear understanding of the role(s) expected to be involved with delivering the required performance, including at different stages of the task.
3. Where a particular level of competence is required, including where a need for improved or additional competence has been identified as an additional mitigating measure against error.
4. Improved understanding of the timing of human performance in relation to the task, particularly during critical task steps that may be time-bound.
5. Improved understanding of what acceptable and successful performance of the task or critical steps within the task looks like, including where improved mitigations against error are required to help to ensure optimal performance.

6. An improved baseline for documenting how critical operations related to the barrier and its function should be conducted.

Points 2 and 3 above strongly link to the competence management system and hence the organisational element of the barrier, with the remaining points providing more support to the operational element. CIEHF (2016) illustrates how human performance standards might be documented and provides examples. However, the connection between performance standards and procedures is not explored. CIEHF (2016) describes procedures as organisational elements since the organisation is prescribing how work should be done, though this contrasts with the definition of organisational elements set out in HAVTIL (2017) and more aligned with their definition of operational elements – namely actions or activities that personnel must perform to realise the barrier function. Liu (2025) includes procedures as a distinct non-technical barrier element. Procedures represent the approved way to successfully complete a goal-oriented task, support competence development and help to ensure consistency of performance. Where procedures have been developed or improved through application of the SCTA process they provide assurance that the information is an accurate representation of "work as done", with improved mitigation against error. There is therefore a strong case for close alignment of non-technical performance standards and procedures within both safety and competence management systems.

Summary and Recommendations

The topic of barrier management is complicated and relates to socio-technical systems that are themselves extensive and complicated. The understanding of and arrangements for managing non-technical barrier elements in the UK offshore industry are generally not as mature as the arrangements for technical, engineered elements and vary more considerably between duty holder organisations. The relative lack of performance standards for non-technical elements is a key weakness, and a vulnerability. There is potential for the industry, including via industry associations, to support improvement through development of guidance. There is also improvement potential for the regulator, including through approaches to inspection and supporting guidance. This paper discusses how an established Human Factors risk management methodology might support the development of performance standards for non-technical barrier elements, and hence how it might help to address the identified gap.

For duty holders, it is recommended that the non-technical elements in the barrier model and barrier management system are examined against the performance standard characteristics set out in CIEHF (2016). Barrier-related critical tasks should be identified and considered within the scope of an SCTA programme. Similarly, SCTA programmes should be considered in relation to the barrier model, and greater attention should be paid to integration and alignment of SCTA with barrier management activities. Development of performance standards should be prioritised, adopting the principle that where a performance standard is lacking the barrier element is only a more general safeguard, and hence the robustness of the barrier element is diminished. Where 3rd party specialists are used to support and facilitate SCTA programmes, information about the relationship between barrier elements and critical tasks should be communicated to them so that tasks can be identified and prioritised for further analysis accordingly. Barrier assurance activities should include non-technical elements in their scope, and barrier health monitoring arrangements must credibly reflect both technical and non-technical elements and changes that affect both the organisational and operational elements.

For the UK offshore regulator, arrangements for inspecting and assessing duty holder capability and performance with non-technical barrier management should be developed into a more structured approach. This should include developing clearer guidelines and success criteria for both inspections and safety case assessments. To support this, functional links between the specialist areas of Human Factors, Management Systems and Verification, and Process Safety should be examined in relation to the topic of barrier management. Lessons from other regulators should be sought and incorporated into the improved structure and approach.

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