Qualitative Data Collection for Human Reliability Analysis in the Offshore Petroleum Industry

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Abstract: Effective Human Reliability Analysis (HRA) requires both a qualitative analysis of potential human errors and a quantitative assessment of the likelihood of those errors. One of the main conclusions from an International HRA Empirical Study is the importance of qualitative analysis when performing HRA.

Although qualitative data collection is relatively well established for HRA in the nuclear industry, there is very little written guidance available on how to perform such data collection. Most HRA methods do not provide guidance on how to do this, even when the method specifies that this activity should be performed. In addition, HRA is still a relatively new concept in the petroleum industry and so there exists little experience in this industry of qualitative data collection for the purposes of HRA and quantification.

The Petro-HRA project is funded by the Research Council of Norway and includes a workpackage to evaluate methods for qualitative data collection, with the aim of developing written guidelines for HRA analysts working in the petroleum industry. This paper describes the objectives and research approach for this workpackage, and the findings to date from interviews with HRA analysts working in the petroleum industry on the Norwegian Continental Shelf.

Keywords: HRA, Human Reliability Analysis, Qualitative Data Collection, Petroleum.

1. INTRODUCTION

Effective Human Reliability Analysis (HRA) requires both a qualitative analysis of potential human errors and a quantitative assessment of the likelihood of those errors [1]. In fact, one of the main conclusions from the International HRA Empirical Study is the importance of qualitative analysis when performing HRA [2]. The study showed that HRA methods will not have an adequate basis to identify important performance drivers and to obtain a realistic human error probability (HEP) estimate unless the HRA includes a qualitative analysis covering a thorough set of scenario conditions and influencing factors.

Although qualitative data collection is fairly well-established for HRA in the nuclear industry, there is very little written guidance available to analysts regarding how to do this. Most HRA methods do not provide guidance on how to perform qualitative data collection, even though the guidance often specifies that this activity should be performed. In addition to this, HRA is still a relatively new concept within the petroleum industry and so there exists little experience within this industry of qualitative data collection for the purposes of HRA and quantification.

The Petro-HRA project, which is funded by the Research Council of Norway, includes a work package to evaluate methods for qualitative data collection. The main aim of this work package is to develop written guidelines for HRA analysts working in the petroleum industry, which will take into account potential constraints or limitations on qualitative data collection. The guidelines will also aim to simplify the approach to enhance quality and consistency in its application. This paper describes the objectives and research approach for this work package. The paper also describes the findings to date from interviews with HRA analysts working in HRA on the Norwegian Continental Shelf (NCS) regarding their experiences of qualitative data collection and the challenges they have experienced.

1.1 Background

The human contribution to the safety of petroleum installations has long been a concern for the industry and for the Petroleum Safety Authority of Norway. In the petroleum industry, quantitative risk analysis (QRA) has been used to estimate the likelihood of failure. To date, QRA has mostly focused on technical barriers and there are no standardized methods for how HRA is performed or incorporated into the QRA.

More recently the Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method has been used for analysis of the human contribution to risk for some petroleum installations in Norway. Some limitations with this approach have been revealed, in part because SPAR-H was developed specifically for nuclear applications and in part because it represents a simplified HRA approach and thus may not be applicable to all scenario types in the QRA. Despite these limitations, the simplicity and apparent flexibility of the SPAR-H method make it a good candidate for further use in the petroleum industry.

1.2 The Importance of Qualitative Data

The U.S. Nuclear Regulatory Commission (NRC) states that "qualitative analysis is an essential part of an HRA" [3, p. 4-1] because a good qualitative analysis provides a foundation for all other steps in the HRA. Lucas et al. [1] argue that effective HRA requires both qualitative modeling of potential errors and quantitative assessment of their likelihood. Le Bot [4, p. 155] extends this idea by stating that "qualitative considerations, based on qualitative observations, are much more significant for determining the final probability than the rough figure obtained from observation."

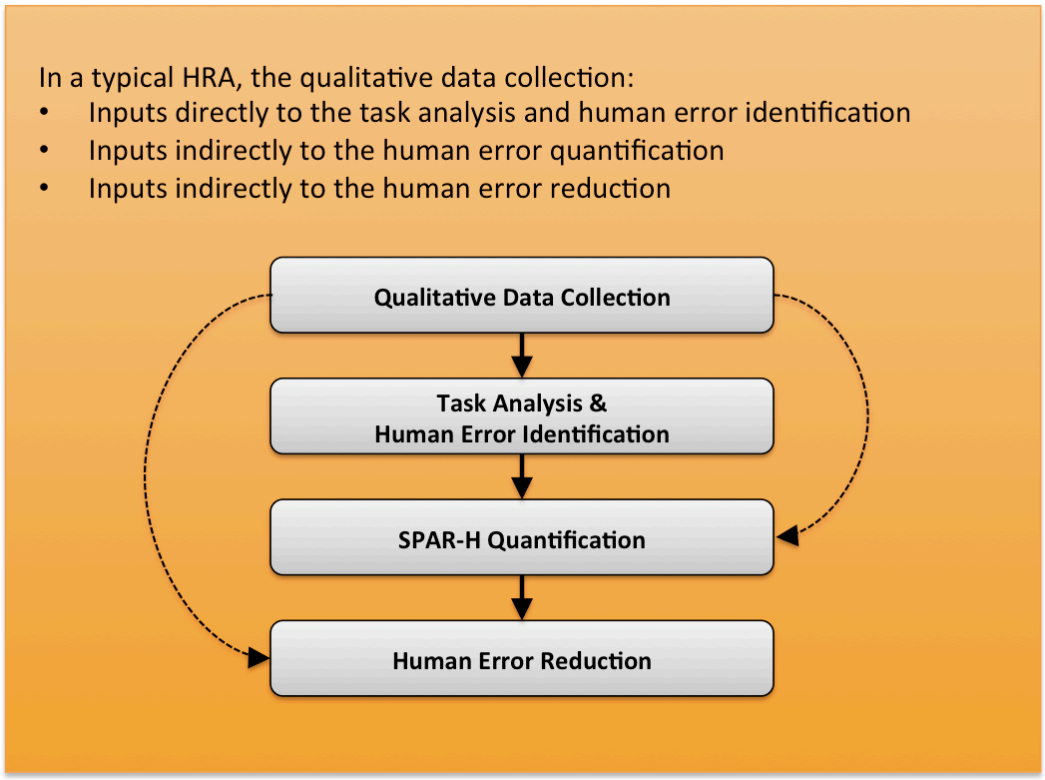

Figure 1: Qualitative Data Collection underpins the rest of the HRA

An International HRA Empirical Study was conducted between 2007 and 2011 to develop an empirically based understanding of the performance, strengths, and weaknesses of different HRA methods currently in use in the nuclear industry. One of the main findings of the study, reported in Forester et al. [2], is that qualitative analysis is of significant importance when performing HRA. The

study showed that, without a qualitative analysis that covers a thorough set of scenario conditions and performance influencing factors, HRA methods will have an inadequate basis to identify important performance drivers and obtain realistic Human Error Probability (HEP) estimates.

However, the International HRA Empirical Study also noted variability in the way analysts perform qualitative analysis, and concluded that this was a significant contribution to variability in the quantitative results of the scenarios analyzed for that study [2]. This may be partly attributed to the fact that the HRA methods used today are not consistent with respect to requirements for and guidance on how to perform qualitative analysis. Indeed, some methods, such as SPAR-H, do not provide any guidance on how to perform a qualitative analysis [5].

1.1 Objectives of the Qualitative Data Collection Study

The primary objective of this study is to investigate the qualitative data collection process and to adapt this for use in Petro-HRA. The study will consider commonly used methods for generic (i.e. non-industry specific) data collection as well as those used within the nuclear industry, where HRA is well established. The study will also consider the methods that have been used so far by HRA analysts working in the petroleum industry, and will seek to compare the advantages, constraints and limitations of the petroleum industry experiences with those from nuclear and other relevant sources.

The aim of the study is to develop practical guidelines for HRA analysts working in the petroleum industry, including interview guides and questionnaires. It is important that the guidelines are practical and take into account the reality of performing HRA in this industry (i.e., potential time constraints, access to personnel, access to documentation, etc.) the ensure that they are usable by analysts in their day-to-day jobs. If the guidelines are considered by the HRA analysts to be useful and practical, it will help to increase the consistency with which they are applied and the quality of the analyses.

2. STUDY OVERVIEW

2.1 Study Plan

The research approach for this study is centered around understanding the opportunities and constraints for qualitative data collection within the North Sea petroleum industry, and adapting best practices from the nuclear industry to support data collection for Petro-HRA. The study is divided into four main tasks, as shown in Figure 2 below.

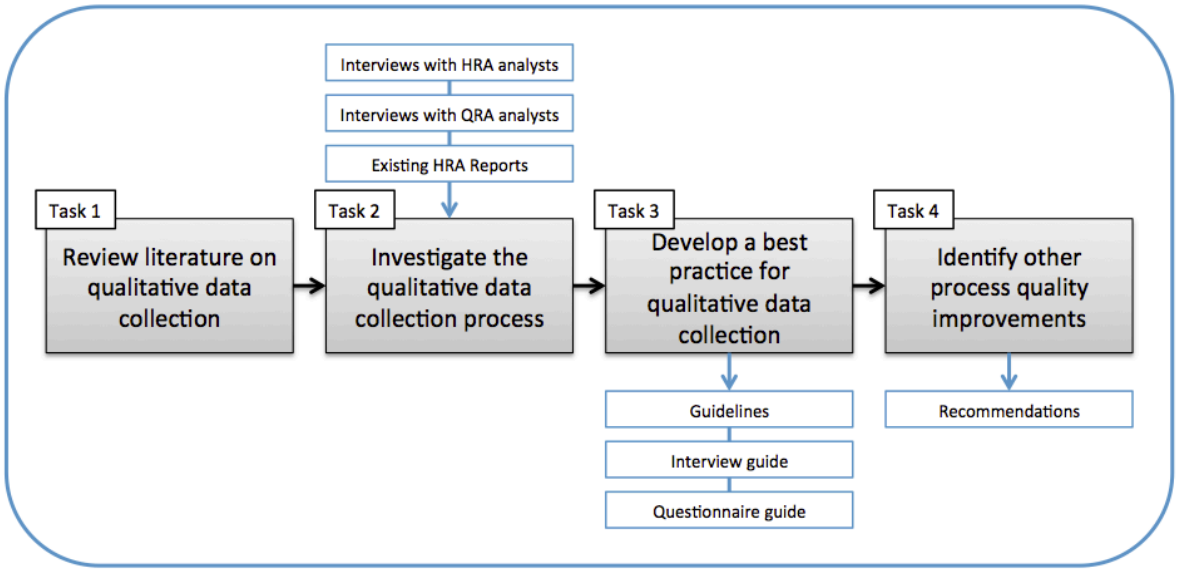

Figure 2: Plan for the Qualitative Data Collection study

2.2 Task 1: Review Literature on Qualitative Data Collection

The literature review will seek to identify methods and techniques for qualitative data collection and best practices from the nuclear and other relevant industries. The literature review will also seek to identify published guidance on what qualitative data should be collected, as well as how this should be done, with emphasis on data to support and inform a SPAR-H quantification (i.e., relevant to the eight SPAR-H Performance Shaping Factors (PSFs)).

2.3 Task 2: Investigate the Qualitative Data Collection Process

To investigate the qualitative data collection process, existing HRA reports using SPAR-H (as made available by Statoil) will be reviewed to understand the methods and techniques that have been used by analysts to date in the Norwegian petroleum industry. Semi-structured interviews will also be carried out with both QRA and HRA analysts working in the petroleum industry to discuss their experience with HRA and to understand the potential limitations and constraints for data collection in this industry.

This task will also seek to evaluate any best practices identified in the literature review by discussing these with HRA analysts to determine their applicability and ease of use. This will form the basis for the development of best practices guidelines (Task 3).

2.4 Task 3: Develop a Best Practice for Qualitative Data Collection

A best practice guideline for qualitative data collection for Petro-HRA will be developed based on the outputs from Tasks 3.1 and 3.2. The aim is to provide practical guidance for HRA analysts regarding what information they should seek to collect and the best means to do this, given the potential constraints that they may have to work within (for example, limited resources, availability of experts or lack of documentation). The best practice will also include guidance on conducting interviews and developing questionnaires as another means of data collection.

The development of the best practice guideline is intended to be an iterative process whereby the guideline will be tested by HRA analysts in the field, and feedback will be obtained to improve the guideline as necessary.

2.5 Task 4: Identify Other Process Quality Improvements

It is anticipated that discussions with HRA analysts and with the other research partners on this project may identify opportunities for additional improvements to the HRA process, for example, when and how the HRA should be integrated into the QRA process. Where identified, recommendations for improvements will be reported.

3. FINDINGS TO DATE

3.1 Work Completed

Task 1 (Review Literature on Qualitative Data Collection), has now been completed, and a literature review report has been delivered to the project. Task 2 (interviews with QRA and HRA analysts) and Task 3 (development of guidelines) are currently underway.

3.2 Findings from the Literature Review

3.2.1 Sources of Qualitative Data

One of the most important sources of data is the plant site or facility [7]. Here, qualitative data can be collected from talking to personnel, from observations in training simulators and from the facility itself, usually via a combination of walking- and talking-through scenarios with experienced personnel. In their guidance on good practices for HRA, the U.S. NRC [8] note that HRA analysts should perform facility walkdowns, field observations, talk-throughs of scenarios and actions of interest with plant operators, trainers or maintenance staff, and observations of simulator exercises. These activities allow the analysts "to confirm judgements and assumptions made from the document review and helps them to obtain a more well-informed understanding of the context for the various actions and scenarios" [8, p. 3-3].

Control room simulators generally constitute excellent sources of qualitative and quantitative data on human error, although experience shows it can be difficult for HRA analysts to gain access to simulators to run the specific scenarios of interest. This is because simulators tend to be used exclusively for training purposes and so data collection for HRA usually has to be combined with training exercises, meaning that the HRA analyst may not always get to observe the scenario of specific interest to the HRA [1]. However, Gertman and Blackman [7) write that "it is highly desirable to conduct simulator trials for specific sequences of interest because you can observe the influence of PSFs rather than making inferences based on factors such as judgement of the relative quality of procedures, training programs, and management effectiveness." Although it is not possible to reproduce all PSFs of interest using the simulator, it still offers a rich source of data for HRA analysts.

Documentation such as operating instructions/procedures, pictures of the man-machine interface and the working environment, training manuals, task and system specifications, engineering and layout drawings, system-specification documents, interlock schedules and even shift logs can provide a rich source of data about the systems and tasks involved in the scenario [9, 10]. Another important data source are event reports as these can provide valuable information about previous abnormal occurrences at the facility and, "because many abnormal occurrences originate from or implicate human performance deficiencies, [event reports] contain much material that is of interest to the human reliability analyst" [1].

3.2.2 Qualitative Data Collection Methods

There are three main methods that are used to collect qualitative data [6, 9]:

- Review and examination of documents,
- Interviews, workshops, focus groups with personnel, and
- Task observation, walk-throughs and talk-throughs.

Analysts will typically use a combination of some or all of these methods to collect qualitative data for the HRA. Gertman and Blackman [7] recommend that the data collection approach is tailored to the quantification method that the HRA analyst intends to use; for example, "if you intend to use THERP, you must collect the data necessary to properly apply the model including all required THERP performance shaping factors (PSFs). On the other hand, if you exclusively use human cognitive reliability (HCR), then you need only collect the necessary time information and the PSFs associated with it" [7, p. 84].

3.2.3 Qualitative Data Collection for SPAR-H

The SPAR-H method does not provide guidance on what kind of qualitative data is needed for a SPAR-H analysis, or how to collect this data. The method assumes that relevant data has been collected by the analyst prior to applying SPAR-H [11]. However, Whaley et al. [11] note that a part

of the supporting qualitative analysis is to identify the main performance drivers, both positive and negative. By reviewing the eight SPAR-H PSFs, the analyst can infer the type of qualitative information that is needed for the remainder of the analysis.

The eight SPAR-H PSFs are: available time, stress/stressors, complexity, experience/training, procedures, ergonomics/human machine interface, fitness for duty and work processes.

3.2.4 Collecting Qualitative Data to Assess Dependency

It is also important to consider dependency during qualitative data collection to ensure that sufficient information is collected for the analyst to be able to assess dependency later in the HRA. Thus the analyst should strive to identify any potential links between tasks that could result in an incorrect mental model, i.e. whether performance of one task is dependent upon a previous task. Whaley and Kelly list four factors for which qualitative data should be collected, within the context of the scenario [11, p. 6]:

- Time (is there enough time to allow forgetting and emptying of working memory),
- Location (introducing new information, potentially interrupting the script),
- Same person or crew (allows for mindset to develop), and
- Cues (which may stimulate the human to think differently).

3.3 Findings from the Interviews

To date, interviews have been held with eight HRA analysts working in the petroleum industry in Norway, the United Kingdome and the United States. Interviews have also been held with one QRA analyst with experience of performing QRA for offshore installations, and one QRA end user based at an onshore installation. The purpose of these interviews was to understand how the QRA and HRA fit together, the approaches and techniques used by HRA analysts, their experience with HRA methods and the challenges they have faced and what kind of information is needed for the HRA and for the QRA.

The interviews covered all aspects of the Petro-HRA project (i.e. did not focus only on qualitative data collection), but the key findings relevant to the qualitative data collection study are summarized here. It is intended to carry out additional interviews with QRA and HRA analysts in 2014.

1. HRA Representation in the QRA

It was reported during these interviews that there are very few human actions modeled in the QRA for offshore installations; this is because most of the safety barrier systems offshore are automatic, with little or no human intervention required in a major accident scenario. Conversely, at the onshore installation, which was visited for one of the interviews, there are no automatic systems and so all of the major accident scenarios in the QRA contain many human actions.

Most of the interviewees reported that HRA is not currently well represented in the QRA. It was speculated that this may be partly due to a lack of availability of HRA experts to do the detailed analysis required, and partly due to the tendency for the QRA to focus on post-initiator events (with few human actions) rather than pre-initiator evens (where there are likely to be more human actions involved). All of the interviewees agreed that there is a need for better representation of human actions in the QRA.

2. Experience with Qualitative Data Collection Methods

Almost all of the interviewees considered a visit to the installation to be the best way to collect qualitative data about the scenario being analyzed. By visiting the installation, the analyst can get a better understanding of how operators perform tasks and the environments in which they do so.

However, for offshore installations at least, it is expensive and not always practical to visit the facility, and so workshops with operators and other subject matter experts are often used as an alternative (or additional) means to collect qualitative data. During the workshop, the analysts will typically talk through the scenario with the operators (sometimes using photographs and plant drawings, etc. in addition), with the purpose of developing a task analysis for the scenario. The workshop participants are usually asked to provide details about the tasks, develop a timeline, identify critical tasks, give their opinions on the presence and effect of different PSFs for each task, etc. This was reported as a typical approach for data collection in the petroleum industry, i.e. the analyst would visit the installation if possible, and then follow-up with a workshop to collect more data and develop a task analysis.

Both the visit to the installation and the workshop require a lot of preparation, if the time spent is going to be utilized effectively. The analysts reported that they will typically review any relevant documentation (e.g. operating procedures, system descriptions, previous analyses, etc.) that is available to them in advance to familiarize themselves with the systems, processes and tasks involved in the scenario. The analysts will consider where errors could occur, and what PSFs could potentially exist and the impact of these, and then discuss and confirm these during the installation visit and/or workshop. Some of the analysts also noted that it is useful to talk to the QRA analysts or senior engineers who have knowledge of the installation to find out more about the scenario.

Three of the analysts interviewed stated that they use the Systematic Human Error Reduction and Prediction Approach (SHERPA) [12] to assist with identification and classification of potential human errors. However, two of the analysts interviewed said that they do not use any systematic method for human error identification; usually they will just ask the operators what errors could occur. The analysts will also look at or ask about existing measures, such as operating procedures and training, which may help to manage any PSFs that are present, as well as possibilities to recover from errors.

3. Challenges for Qualitative Data Collection

Lack of availability of knowledgeable people was reported as a main challenge for data collection for HRA; it can often be difficult to get access to the right people to ask questions. The analysts also noted that offshore operators tend to go to a lot of workshops, and so it can be difficult to engage them and keep them interested to get their input to the task analysis. But some of the analysts noted that these challenges depend very much on the level of experience of the operators, and in most cases operators are very receptive to providing information, even after the workshop (e.g. if contacted by email or telephone).

Another reported challenge with qualitative data collection can be to ensure that the information received is objective, and not overly optimistic or pessimistic. For this reason, the interviewees stated that they try to talk with several operators, and also try to talk with simulator trainers as they can often provide valuable, objective insights about how operators react in the simulated scenarios.

Another constraint that was mentioned by almost all of the interviewees was the time available to complete the analysis; in most cases, analysts felt that it was difficult to do a thorough analysis within the time allocated. Some analysts noted that one day is not enough time to run the task analysis workshop, but it is difficult to say how much time is needed because it depends on the number and complexity of the scenarios being analyzed.

4. Use of the Qualitative Data

In addition to using the qualitative data to populate the task analysis and inform the quantification, the QRA analyst reported that this qualitative information is also of use to the QRA, as it substantiates the calculated HEP; the QRA analyst can use this data to see how the HEP has been derived and the information underpinning it.

The HRA may also include a number of assumptions, for example, about predicted human-system interactions under certain scenario conditions. It is important for the QRA analysts to know about these assumptions so that they can assess the impact on the HEP (and therefore on the overall QRA) if any of these assumptions change.

3.4 Feedback on Initial Guidelines for Qualitative Data Collection

Initial guidelines were developed for qualitative data collection for an offshore installation visit and for an onshore task analysis workshop. Both documents were developed based on experience of qualitative data collection and HRA from the UK Nuclear industry, as they were developed relatively early in the project (to take advantage of the scheduling of the offshore visit and task analysis workshop) when it was too early to incorporate any findings from the literature review or interviews. The guidelines were tested by an HRA analyst during a real-world analysis, and a short discussion was held afterwards to gather feedback on the documents.

The guideline for the installation visit was 2-pages in length, and contained advice on preparing for the installation visit, methods for data collection during the visit, and suggestions for types of data and information to collect. The guideline for the task analysis workshop was 3-pages in length and contained advice on how to prepare for the workshop and considerations for how to run the workshop.

The feedback from the analyst was that both documents were useful, provided a structure for the visit and the workshop, and also provided a good checklist to prompt thinking and make sure no major considerations were overlooked. However, the analyst reported that both documents need to be more detailed, as was anticipated by the project.

4. CONCLUSIONS

The literature review performed for this study confirmed that there is relatively little published literature on how to perform qualitative data collection for HRA, either in terms of recommended techniques or what kinds of data to collect. Although most HRA methods state that qualitative data is essential to inform the quantitative analysis, the method guidance tends not to provide instructions regarding how to collect this data. Although there exists some published material on performing HRA for the petroleum industry [13, 14], this review did not uncover any literature detailing either experiences or methods for collecting qualitative data for HRA from onshore or offshore petroleum installations. However, the review did uncover relevant literature on techniques and methods for qualitative data collection for HRA, primarily for the nuclear industry, but which are relevant for use in the petroleum industry also. The findings from the literature review will be used to inform the development of the guidelines for analysts conducting qualitative data collection for Petro-HRA.

Ten interviews have been conducted to date for this study, with eight HRA analysts, one QRA analyst and one QRA end user. From the interviews, it can be concluded that human actions are not currently well represented in the QRA, and that HRA is needed to ensure that the complexities and impact of the human actions in major accident scenarios are sufficiently understood and appropriately represented in the QRA.

The best method for qualitative data collection is a visit to the installation so that analysts can talk to operators, see the plant and systems, and observe the environments within which operators perform tasks. However, access to installations (especially offshore) is not always possible and so an additional means of collecting qualitative data, which is often employed in the petroleum industry, is to hold onshore workshops with operators and other subject matter experts. The usefulness of the workshop and the quality of the data gathered depends on a number of factors, including how well the HRA analyst prepares for the workshop, the attendance of experienced and knowledgeable participants, and the ability of the analyst to keep the participants interested, engaged and on-track throughout the workshop.

The main challenges experienced for qualitative data collection are a lack of availability of knowledgeable people for interviews or workshops, ensuring that the data collected is objective, and a shortage of time for the overall HRA.

5. NEXT STEPS

It is intended to carry out additional interviews with QRA and HRA analysts throughout 2014. A preliminary set of guidelines for qualitative data collection has been developed (for an offshore installation visit, and for an onshore task analysis workshop), and feedback has been obtained from an HRA analyst who used these during an analysis in 2013. The guidelines will be developed further, based on the findings from the literature review and the interviews, and these will be tested in more detail by the project group during a simulated HRA which is scheduled to take place in Autumn 2014.

The intention of the overall Petro-HRA project is to prepare a complete set of guidelines by the end of 2014, covering the full HRA process from identification of scenarios for analysis through to quantification of those scenarios. The guidelines will then be made available to HRA analysts for testing in 2015.

Acknowledgements

The present study was supported by the Petromaks Programme of the Research Council of Norway, Grant no. 220824/E30 "Analysis of human actions as barriers in major accidents in the petroleum industry, applicability of human reliability analysis methods (Petro-HRA)". Financial and other support from The Research Council of Norway, Statoil ASA and DNV-GL are gratefully acknowledged. This paper represents the opinion of the author, and does not necessarily reflect any position or policy of the above-mentioned organizations.

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