Analysis of human actions as barriers in major accidents in the petroleum industry, applicability of human reliability analysis methods (Petro-HRA)

Karin Laumann[a], Knut Øien[b], Claire Taylor,[c] Ronald L. Boring,[d] Martin Rasmussen[a]

[a] Norwegian University of Science and Technology, Trondheim, Norway

[b] SINTEF, Trondheim, Norway

[c] Institute for Energy Technology, Halden, Norway

[d] Idaho National Laboratory, Idaho Falls, US

Abstract:

This paper presents an ongoing project called "Analysis of human actions as barriers in major accidents in the petroleum industry, applicability of human reliability analysis methods (Petro-HRA)". The primary objective of this project is to test, evaluate and adjust Human Reliability Analysis (HRA) methods for use in quantifying the likelihood of human error and identifying the impact of human actions on the post-initiator barriers in the main accident scenarios in the petroleum industry. This project has chosen the HRA method "Standardized Plant Analysis Risk - Human Reliability Analysis" (SPAR-H) as the main method to adjust to a petroleum industry context. SPAR-H is a quantification method and it does not include description of the "qualitative data collection," "task identification" and "task analysis" part of an HRA analysis. This project aims at developing guidelines for all the steps in performing an HRA analysis with SPAR-H in the petroleum industry.

Keywords: Human Reliability Analysis, SPAR-H, Quantitative Risk Analysis, Petroleum Industry, Human Error Probabilities.

1. INTRODUCTION

In this paper an ongoing project called "Analysis of human action as barriers in major accident in the petroleum industry, applicability of human reliability analysis methods (Petro-HRA)" is presented. This project is funded by The Research Council of Norway, PETROMAKS program. Statoil and DNV GL are industry partners in this project. The industry partners cover 20 percent of this projects funding. Institute for Energy Technology is the project owner. SINTEF, Idaho National Laboratory and Norwegian University of Science and Technology participate in the project. The project period is from October 2012 until October 2016.

Quantitative risk analysis (QRA) is one of the main tools for risk management in the petroleum industry. Skogdalen and Vinnem (1) have shown that QRAs differ on the extent to which they incorporate human and organizational factors. One reason for this might be a lack of research on how to adjust HRA methods to the petroleum industry and how the results of the HRA analysis should be included into the QRA. Thus the primary purpose of this project is: "to test, evaluate and adjust Human Reliability Analysis (HRA) methods for use in quantifying the likelihood of human error and identifying the impact of human actions on the post-initiator barriers in the main accident scenarios in the petroleum industry".

Since Statoil has already evaluated some HRA methods and come to the conclusion that the Standardized Plan Analysis Risk - Human Reliability Analysis (SPAR-H, 2,3) seemed to be the most applicable method (4) this project chose SPAR-H as the HRA method to adjust to a petroleum industry context. Since SPAR-H is mainly a quantification method it does not describe all steps of performing an HRA analysis such as "qualitative data collection", "task identification" and "task analysis". This project will develop guidelines for all the steps of performing an HRA analysis.

This project has four work packages:

Work Package I (WP I):	Evaluation and adjustment of contextual factors for human actions in accident scenarios in the petroleum industry.
Work Package II (WP II):	Task analysis and human error identification analysis (human error analysis and reuse methodology).
Work Package III (WP III):	Qualitative data collection: Interviews, observations and questionnaires.
Work Package IV (WP IV):	Studies for the quantification by an expert group.

Next, the purpose, tasks and outcomes of each of these work packages are presented.

2. WORK PACKAGE I – PSFs FOR THE PETROLEUM INDUSTRY

2.1. Purpose

WP I has several objectives: The first objective is to develop performance shaping factors (PSFs), PSF levels, PSF multipliers and nominal values that are adjusted to the petroleum industry. The second objective is to evaluate other HRA methods than SPAR-H for use in the petroleum industry and develop suggestions for other methods if we find that SPAR-H is not adequate or not sufficient for some tasks, scenarios or contexts. The third objective is to develop a guideline on human error reduction. The fourth objective is to compile the new guidelines for the petroleum industry developed in all of the work packages into one guideline and test it. If necessary the guideline will be changed based on these tests.

2.2. Tasks

The tasks in WP I are briefly described below.

2.2.1. Task 1.1: Literature review

Boring and Blackman (5) describe that most of SPAR-H multipliers originated from THERP (6). THERP is a method that is over 30 years old. In this literature review we focus on newer research on PSFs, PSF levels and PSF multipliers. We have also done a literature review on other HRA methods than SPAR-H.

2.2.2. Task 1.2: Evaluate other methods

In this task the suitability of SPAR-H for different types of scenarios/tasks in the petroleum industry is evaluated. If tasks are identified where SPAR-H is not a suitable method alternative methods will be evaluated. As an alternative to SPAR-H, a method that has another approach is investigated. Most of the first generation HRA methods like for example THERP and HEART have a similar approach as SPAR-H and is not considered as an alternative. A method like ATHEANA which has another approach than SPAR-H will be considered for some tasks. A difference between ATHEANA and SPAR-H is that in SPAR-H only the nominal scenarios (or the most likely scenarios) are analyzed. In an ATHEANA analysis deviation scenarios which are scenarios that make the operators' task more difficult are also considered. The conditions that might make the operators' tasks more difficult are both installation specific conditions and PSFs. One example of such a deviation scenario could for example be difficult weather conditions leading to an increase in complexity. ATHEANA gives guidance for how to come up with these types of deviation scenarios. The likelihood for human failure in ATHEANA is a combination of how likely the nominal and deviation scenarios are and the likelihood of human errors in the different scenarios. For calculation of human failure probabilities in ATHEANA expert judgments is used. ATHEANA describes in detail how these expert judgments should be performed. However, it is possible to use the ATHEANA guideline for analyzing the possibility for deviation scenarios and then use SPAR-H as the quantification method.

Several approaches are used in completing this task:

Approach 1: This task is closely connected to the literature review on other HRA methods. The literature review is used to discuss alternative methods.

Approach 2: We have performed interviews with consultants who have performed HRA analyses in the petroleum industry and in the nuclear industry. The consultancies that have performed HRA analyses in the petroleum industry have mainly used SPAR-H. From the interviews we got information about the consultants view on the suitability of SPAR-H analyses for different tasks and scenarios in the petroleum industry.

Approach 3: We investigate the suitability of SPAR-H for petroleum industry tasks though QRA reports and associated HRA reports and perform an evaluation of the suitability of SPAR-H in these reports.

Approach 4: A project memo will describe how an ATHEANA analysis might be adopted for some scenarios/tasks were context (installation conditions and PSFs) seems to have a large possibility to affect the operators' task. It will be evaluated if this approach together with SPAR-H could be a useful.

Approach 5: To evaluate SPAR-H as a method to perform HRA in the petroleum industry is an on-going activity in the project. Especially in the task "Selected SPAR-H analyses" the use of SPAR-H as a quantification method will be evaluated.

2.2.3. Task 1.3: Selected SPAR-H analyses

In this task, tests of SPAR-H analyses are performed for different scenarios with the purpose of collecting data as input to other tasks and to test the guideline that we are developing.

One approach is that the Petro-HRA project group follows consultants who work on HRA analyses with SPAR-H, while the Petro-HRA project group performs a separate and parallel data-collection and analysis of the tasks. By doing this we get hands-on experience on how our suggested guidelines would work in a real-life setting.

The Petro-HRA project group also performs their own analysis of some human failure events to test the guidelines we are developing. These analyses should be considered for test and research purposes only, as they will be performed using an unpublished method that is still under development.

2.2.4. Task 1.4: Relevance of the PSFs

The PSF descriptions and the PSF levels in SPAR-H are evaluated and changed to make them more applicable to the petroleum industry. The value of the multipliers and nominal values have been reviewed and they will be changed.

The literature review on PSFs gives input to this task. The literature review is used to develop a clearer and more consistent description of the PSFs than the description found in the current SPAR-H manual (2).

Interviews with consultants who have performed HRA analyses in the petroleum industry and in the nuclear industry provide information on positive and negative aspect of using SPAR-H as a quantification method.

Investigation of QRA reports and associated HRA reports provide information about how the consultants in the petroleum industry have used the SPAR-H guidelines and give information about potential improvement areas in the existing guidelines on the quantification part of the method.

New descriptions of PSFs and PSFs levels are developed. New multipliers and nominal values are developed from the literature review, from collection of objective data or from expert judgement.

2.2.5. Task 1.5: Collect objective HRA parameters data

In this task the possibilities to collect objective HRA data within the petroleum industry is explored. One of the most profound objections to HRA is the lack of objective data. For SPAR-H the nominal values and the multipliers for the PSF levels should be based on objective data.

It is challenging to find nominal failure rates since it is difficult to identify failures without PSFs present. In this activity we explore Statoil's databases to see if we can find data on tasks that can be considered nominal.

Another purpose of this activity is to explore how information from simulators and training instructors can be used in an HRA analysis. For this activity, the Petro-HRA researchers are going to visit the drilling and process simulators to explore what kind of information that is possible to obtain from the simulators (what they train on, how they train, how they register information from training, etc.). The purpose of this activity is not only to obtain the data itself, but also to explore the possibility to obtain data from simulators for an HRA analyst. We also expect that the simulator trainers can give information about PSFs in accident scenarios that could be used to evaluate the adequacy of the SPAR-H PSFs and PSF multipliers for the petroleum industry.

2.2.6. Task 1.6: Develop the guideline and test the method

In this task the Petro-HRA guideline will be compiled and the developed guideline will be tested on human tasks in a QRA analysis. The developed guideline will be reviewed and tested by consultants performing HRAs. The approach for testing the guideline is that consultancies use the initial guideline for their analyses and provide us feedback. The guideline will be revised if necessary based on the feedback.

A preliminary suggested structure/outline for the guideline is as follows:

Chapter 1:	Objective; Guide to the reader; etc.
Chapter 2:	QRA in the petroleum industry
Chapter 3:	Overview of the Petro-HRA analysis
Chapter 4:	SPAR-H limitations and use of alternative methods
Chapter 5:	Qualitative data-collection
Chapter 6:	Task analysis
Chapter 7:	Human error identification
Chapter 8	Human error modelling
Chapter 9:	Human error quantification
Chapter 10:	Human error reduction
Chapter 11:	Expert judgements in Petro-HRA analysis
Chapter 12:	Documentations of the Petro-HRA analysis
Chapter 13	HRA integration in QRA
Chapter 14:	Petro-HRA guidelines for HRAs in the design phase
Appendices:	Examples of task analysis and task analysis library

2.2.7. Task 1.7: SPAR-H human error reduction

The purpose of this activity is to develop a guideline on how to suggest strategies for human error reduction based the on SPAR-H analyses. Few SPAR-H analyses have been performed in the petroleum industry making it difficult to investigate the effect of suggestions for human error reduction. However, it is possible to investigate the reports that exist (in the petroleum and the nuclear industry) and evaluate the suggestions for human error reductions given. A guideline on how to suggest human error reduction based on SPAR-H will be developed. A workshop will be held to evaluate the suggested guideline.

2.3. Outcomes

The outcome of this work package is:

- A literature review on PSFs, PSF levels and multipliers
- A literature review on HRA methods
- New descriptions of SPAR-H PSFs and PSFs levels which are adjusted to the petroleum industry
- Development of new nominal values and multipliers which are adjusted to the petroleum industry
- A document that describes how an ATHEANA analysis could be done in addition to a SPAR-H analysis
- A document that describes the investigation of the possibility to collect objective HRA parameters and the objective data that we can possibly obtain
- A guideline that describes how suggestions for human error reduction based on the SPAR-H analysis should be given
- A guideline that describes how the total HRA process with SPAR-H should be performed (this is the main outcome from this project).

3. WORK PACKAGE II – TASK ANALYSIS AND HEI ANALYSIS

3.1. Purpose

The purpose of WP II is to simplify the task analysis and human error identification analysis by looking at how much of the task analysis can be reused for a new installation. This work package will investigate how similar or different the analyses are for the same type of tasks at different installations. Another goal is to explore the differences in performing task analysis and human error identification for different analysts and to explore the possibility for guidelines that reduce the differences between analysts.

3.2. Tasks

There are seven tasks associated with WP II, as briefly explained below.

<u>3.2.1. Task 2.1: Literature Review</u>

Only minimal guidance exists for decomposing timelines of events into human failure events (HFEs) required in HRA and PRA (and QRA). Numerous methods for task analysis exist, which functionally can produce HFEs, but there remain gaps between the product of a task analysis and the required HFEs. Moreover, no explicit guidance exists in SPAR-H on how to define HFEs. This task will document the process of using task analysis in the petroleum industry to craft HFEs at the right level of granularity for analyses using SPAR-H or other HRA methods.

<u>3.2.2. Task 2.2: Identify Target Systems and Defined Situations of Hazard and Accident</u>

In this task, an identification and description of target systems will be performed. Within these target systems, existing analyses will be reviewed to determine the scope of coverage and potential areas of overlap for human activities. Subject matter experts involved in the development of the analyses will be interviewed as required.

3.2.3. Task 2.3: Identify Human Tasks in QRA

Building on Task 2.2, additional risk-centred documentation will be reviewed, in particular existing QRAs to identify HFEs. An emphasis will be placed on extracting commonalities across the HFEs and in identifying any potential gaps that might be addressed in the HRA.

3.2.4. Task 2.4: Task Analysis and Human Error Identification for Identified Systems

Using the approach formulated in Task 2.1 and information gathered in Tasks 2.2 and 2.3, a task analysis will be performed for the HFEs. The goal of walking through the task analysis is to determine deviation paths that could result in different analysis outcomes, e.g., different errors resulting from different contexts. This information will help to construct generic HFEs and scenario-specific variants of those HFEs. A particular emphasis of the task analysis will be on collecting the qualitative assumptions necessary to complete the SPAR-H PSF assignments.

3.2.5. Task 2.5: Compile Library of Tasks and Human Errors

The product of Task 2.4 will be catalogued and documented in a form suitable for reuse. The catalogue or library will include an indexed search method for identifying and customizing relevant HFEs for a QRA. The library will be made available in electronic form, such as a database or spreadsheet that can be made available to analysts.

3.2.6. Task 2.6: Validate Library of Tasks and Human Errors

The approach for generalizing or reusing analyses outlined in Tasks 2.4 and 2.5 will be validated. A validation plan will be developed to compare generic case HFEs and reused/customized HFEs against a cross section of analysis scenarios. QRA, HRA, and human factors experts will be enlisted to implement the HFE-reuse method, and results will be documented. The goal of the validation exercise will be to ensure that the HFE-reuse method can be successfully applied by QRA (and related) experts and that the resulting HFEs are accurate. Any observed difficulties with the approach will be documented and used as the basis for refinements toward the final approach.

3.2.7. Task 2.7: Develop Guidelines to Apply Library

Basic use of the information from the library developed in Task 2.5 and validated in Task 2.6 will be documented in the form of a user guide for QRA and HRA experts. This guide will include overviews of scenarios covered in the library, instructions on how to reuse existing analyses, instructions on how to tailor analyses under related but different circumstances, and instructions for when to apply a new analysis and how to add it to the library.

3.3. Outcomes

As noted, the ultimate goal of this work package is to create the library of reusable human error analyses. To do so requires developing appropriate guidance on how to perform a task analysis suitable for SPAR-H in the context of a petroleum QRA, comparing existing analyses, completing new analyses, determining similarities and differences across analyses, cataloging these analyses, and documenting them. Specifically, the products of the seven tasks associated with WP II are:

- A literature review on existing approaches to task decomposition and analysis in HRA and guidance for use in the Petro-HRA project
- A synopsis of target systems in QRA and opportunities for human errors covered therein
- A synopsis of human tasks and human failure events (HFEs) in existing QRAs

- Example task analyses that serve as generic HFEs for reuse
- A catalog of HFEs and corresponding task analyses
- A validation conducted by having QRA experts use the HFE catalog
- A user guide on the reuse of the HFEs in the catalog

4. WORK PACKAGE III – QUALITATIVE DATA COLLECTION

4.1. Purpose

The purpose of WP III is to investigate the qualitative data collection process and to adapt this for use in Petro-HRA. The most commonly used methods for generic (i.e. non-industry specific) data collection will be investigated, as well as those used within the nuclear industry where HRA is well established. This work package 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 work package is to develop a guidance document on qualitative data collection for HRA analysts working in the petroleum industry, which will include interview guides and questionnaires. The intention is to produce practical guidelines which take into account the reality of performing HRA in this industry (i.e., potential time constraints, access to personnel, access to documentation, etc.).

4.2. Tasks

The research approach for this work package is centered around understanding the opportunities and constraints for qualitative data collection within the 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 described here.

4.2.1. Task 3.1: 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 PSFs).

4.2.2. Task 3.2: Investigate the Qualitative Data Collection Process

To investigate the qualitative data collection process, existing HRA reports using SPAR-H will be reviewed to understand the methods and techniques that have been used by analysts to date in the 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 (in Task 3.3).

4.2.3. Task 3.3: 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.

4.2.4. Task 3.4: 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.

4.3. Outcomes

As noted earlier, the main outcome of this work package will be a best practice guidance document on how to perform qualitative data collection for HRA in the petroleum industry, which will include guidance on how to conduct interviews and how to develop questionnaires. In addition there are specific deliverables related to each task in this work package, as listed below:

- A literature review on qualitative data collection methods and techniques
- An initial summary of the findings from the interviews with HRA and QRA analysts
- A more detailed report on the findings from the interviews with HRA and QRA analysts
- A draft validation report of the guidance documents, following initial testing by HRA analysts
- A final validation report of the guidance documents, which will incorporate feedback from the testing phase
- A summary report for WP III

5. WORK PACKAGE IV – EXPERT GROUP QUANTIFICATION

5.1. Purpose

The purpose of WP IV is to develop systematic expert judgment processes for evaluation and validation of parameters as part of the adaptation and regular use of the SPAR-H method.

For the adaptation of the SPAR-H method, expert judgment may be needed in the validation and evaluation of the nominal HEP values (for diagnosis and action) and the multiplier values (ranges of values) of the PSFs if the validation cannot be supported by objective data. For the regular use of the SPAR-H method expert judgment will be needed for the assignment of the PSF multiplier values. Each of these foreseen applications of expert judgment requires the development of specific user guidelines or expert judgment processes within the Petro-HRA project.

The user guidelines are developed for a) validation/evaluation of nominal values, b) validation/evaluation of PSF multiplier values, and c) rating of PSFs in regular use of the method.

5.2. Tasks

There are four tasks associated with WP IV, as briefly explained below.

5.2.1. Task 4.1: Familiarization and Problem Description

Familiarization with SPAR-H in general and the potential need for expert judgments in the SPAR-H analysis in particular. Description of how expert judgments may be needed in SPAR-H, e.g. for which parameters, and include this problem description in the expert judgment guideline (Task 4.3). This task was performed and documented in 2013 [7].

5.2.2. Task 4.2: Literature Review on Expert Judgment in Human Reliability Analysis Methods

Performing a literature review on expert judgment, particularly related to application in human reliability analysis and including this in the expert judgment guideline (Task 4.3).

5.2.3. Task 4.3: Develop Expert Judgment Process

Development of an expert judgment process and guideline specifically adapted for use in HRA. The parameters to be quantified are HRA parameters, and they will be included as examples in the guideline. The development will start with an existing expert judgment guideline [8,9], and adapt this for use in HRA based on input from WP I and WP III, and from Tasks 4.1 and 4.2.

Two expert judgment processes have been prepared. The first process is related to the evaluation/validation of parameters in SPAR-H/Petro-HRA, i.e. the NHEPs and the PSF multiplier values, whereas the second process is related to the determination of PSF multiplier values in the regular use of Petro-HRA.

In Task 4.3 the initial guideline will be updated based on input received from Task 4.2 “Literature Review on Expert Judgment in Human Reliability Analysis Methods”, Task 3.2 “Qualitative data collection process” and Task 1.4 “Relevance of PSFs”. The expert judgment process (the second process) will be tested and a test report will be prepared and delivered at the end of 2014.

5.2.4. Task 4.4: Evaluate/validate HRA Parameters

Using the expert judgment process (the first process) developed in Task 4.3 to evaluate/validate those SPAR-H parameters (nominal values and multiplier values) that lack sufficient objective data from WP I.

5.3. Outcomes

The main products of the four tasks associated with WP IV are:

- Familiarization and problem description
- A literature review of expert judgment in HRA
- An initial expert judgment guideline
- An expert judgment test report
- A final expert judgment user guide
- An expert judgment validation report
- A summary report for Work Package IV

6. CONCLUSION

This paper has described an ongoing project to develop an HRA method to be use in QRA in the petroleum industry. The main objective of the project is to develop a guideline for the total HRA process (task identification, task analysis, qualitative data collection, human error quantification, human error reduction and documentation of analysis) that is adjusted to the petroleum industry. The guideline developed in this project can be used to more systematically investigate the likelihood of human errors in future QRAs in the petroleum industry.

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