A TASK LIBRARY FOR PETROLEUM APPLICATIONS IN HUMAN RELIABILITY ANALYSIS

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This paper outlines a repository of information on human reliability analyses (HRAs) completed for the petroleum industry. The HRA library serves multiple purposes. It is a database of legacy HRAs that are translated into a standard template for reuse to minimize redundant analyses and facilitate efficient transfer of key assumptions to contemporary applications. It is also a tool to ensure consistency and completeness of future analyses. The library indexes nine aspects of each HRA. It is not required nor assumed that all fields will be populated based on legacy HRAs, but the classification ensures that where such information is available, it can be successfully catalogued.

I. PURPOSE OF A LIBRARY OF HUMAN RELIABILITY ANALYSES

A significant challenge of human reliability analysis (HRA) is capturing lessons learned from previous analyses and finding opportunities to reuse parts of analyses that may be related to the current topic of analysis. As HRA is adapted from nuclear power plant applications to the oil and gas domain,[1,2] there is a particular need to review previous HRAs and find ways to reuse relevant information. Offshore facilities may feature considerable overlap in their installation and operation, and a key way to achieve analysis efficiency and completeness is by reviewing related previous analyses.

One of the primary concerns with doing a detailed HRA is that it is very resource intensive. The review of human actions often requires extensive input from operators and other subject matter experts as well as extensive time by the analysis team to complete the HRA. Yet, many aspects of this analysis are similar to earlier analyses. There are tremendous efficiencies to be won by identifying the overlap between analyses, allowing analysts to reuse relevant portions.

Efficiency must not come at the expense of accuracy or completeness, of course. Another challenge in completing HRA is ensuring that the analysis models the entire details of the event or scenario. Having access to prior analyses ensures that the modelling assumptions can be considered and that a variety of angles can be considered. Each reviewer of the analysis benefits from the previous analysts' insights while having the opportunity to add details that may have been overlooked in earlier analyses.

This twofold mission—efficiency and completeness—underlies the need to create a library of previous and future HRAs in the petroleum sector. By creating an HRA library, future analyses will benefit by having a standard for record-keeping, while the review of earlier analyses will serve to highlight effective analyses and identify analysis gaps.

While it is possible to capture quantitative data such as human error probabilities in the library,[3,4,5] quantification is often linked to the particular HRA methods employed in the analysis. Additionally, the output of many quantitative HRA methods is compressed and may omit important qualitative steps toward understanding the analysis underlying the final numbers. Thus, for purposes of analysis reuse, it may be more beneficial to capture the qualitative portion of the analysis including the definition of the human failure events, the particular tasks being performed by the operators of the system, and analysis assumptions such as reasons for particular degraded performance. These may broadly be considered part of the task analysis in the HRA. The purpose of the HRA library described here is to capture task analysis details that can be reused in similar HRAs.

II. SPECIAL CONSIDERATIONS FOR THE LIBRARY

The specific context for the development of the HRA task library is the Petro-HRA method.[2] This method, commissioned by the Norwegian Research Council with support from Statoil, seeks to create a standardized approach to performing HRA for oil and gas facilities on the Norwegian continental shelf. The method was developed based on best practices for qualitative analyses and using a quantification framework based on the Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) method.[6] In this context, it is important to understand that there exist numerous Norwegian HRAs created prior to the development of the Petro-HRA method. These HRAs use different methods and encompass varying degrees of completeness. A byproduct of the HRA task library is the classification of existing analyses according to the general process and taxonomy of the Petro-HRA method. As such, the library serves—to the extent possible—to translate existing analyses into a framework compatible with Petro-HRA method.

The task library is not a database but rather an index of relevant pieces of the analysis. The key to reuse is for analysts to be able to identify significant areas of overlap between their current HRA and an existing HRA. As such, the library focuses on helping analysts find relevant information amid the archived documentation that will support the new analysis. At the same time, analysts that follow the new Petro-HRA method[2] may avail themselves of the tools in the library that act as a template for the method.

The Petro-HRA library provides a specific structure that matches the steps in the Petro-HRA process.[2] However, prior to the development of the Petro-HRA method, there was wide variety in HRAs. Although these historic analyses do not conform to the Petro-HRA guidance, they may still provide valuable insights on HRA for petroleum systems. As such, the Petro-HRA library includes special sections to capture as much relevant information as feasible from these legacy analyses.

III. LIBRARY STRUCTURE

The task library indexes nine aspects of the HRA. It is not required nor assumed that all fields will be populated based on available legacy HRAs, but the classification ensures that where such information is available, it can be successfully catalogued. New analyses completed according to Petro-HRA guidance will readily fit the task library structure. The nine aspects of HRA in the task library are as follows:

1. *A clear description of the type of systems and installations being analyzed.* To facilitate searches on this information, this index includes two levels of classification—both the general installation family and the specific installation. The general installation family includes:

    - On-shore facilities
    - Fixed production installations
    - Floating production installations
    - Mobile installations
    - Other

    Specific installations include:

    - Fixed on the seabed
    - Semi-subs
    - Floating production storage and offloading
    - Tension leg platform
    - Bridged installations
    - Wellhead installations
    - Jackups
    - Floatels
    - Drilling rigs
    - Transport vehicles
    - Other

2. *A description of defined situations of hazard and accident (DSHAs) that are implicated in the analysis.* DSHAs serve as a useful classification and are standardized across the Norwegian oil and gas industry.[7] Relevant DSHAs include:

    - Non-ignited hydrocarbon leak
    - Ignited hydrocarbon leak
    - Well incident/loss of well control
    - Fire/explosion in other areas (non-hydrocarbon)
    - Ship on collision course
    - Drifting objects
    - Collision with field related vessel
    - Structural damage/stability/mooring/positioning failure
    - Leakage from subsea systems/pipelines/risers/flowlines/loading buoy/loading hose
    - Damage on subsea systems/pipelines/diving gear caused by fishery equipment
    - Evacuation (precautionary/emergency evacuation)
    - Helicopter accident
    - Man over board
    - Serious injury
    - Serious illness/epidemic
    - Blackout
    - Non-operational control room (*not in use*)
    - Diving accident
    - Release of hydorcarbons
    - Loss of control of radioactive source (*not in use*)
    - Falling objects
    - Other

3. *Copies of the task analysis.* A task analysis may be included in any reasonable form (e.g., document or spreadsheet). As outlined in the Petro-HRA guideline,[2] the task analysis and human error identification should include documentation of all assumptions made during the analysis. This can include tasks that were not analyzed because they were not risk significant. The reasons for exclusion should be clearly documented.

4. *A listing of the human failure events.* The human failure events should include the short title and a short but comprehensible description, including the systems affected and the consequences of the failure. The DSHAs may form the basis of the human failure events, but they are not interchangeable.[8] Additional analysis may be necessary to ensure historical HRAs align to a human failure event level of analysis.

5. *Links to event and fault trees.* The HRA will ideally show the relationship between multiple human failure events and between human failure events and hardware faults. Such a depiction will allow integration of the HRA into probabilistic safety assessments and quantitative risk analyses.

6. *Links to the quantification worksheets completed for the human failure events.* These should include any assumptions made that shaped the analysis. These assumptions should detail to a sufficient degree such that the analyst can reconstruct the quantitative portion of the analysis.

7. *A lessons learned synopsis from the analysis.* These lessons learned may take the form of insights into improving the process of conducting the analysis or specific information that was gathered and that proved instrumental in shaping the analysis.

8. *Links to source documents that supported the analysis.* These documents may be proprietary, and access rights may be limited to some source materials.

9. *A description of other analyses that have made use of this information.* If an analyst references or reuses an existing analysis, the new analysis should cross-reference the earlier source analysis. One observed limitation of

the historic Nuclear Computerized Library for Assessing Reactor Reliability (NUCLARR)[5] was its tendency to include analyses based on other analyses, resulting in an overconfidence in certain recycled human error probabilities. Reuse must always include clear reference to its sources in order to prevent overgeneralizing analyses or propagating potentially erroneous analyses. New insights into historic analyses should afford the opportunity to trace forward through subsequent analyses that may be based on these sources.

Note that because some of this information is proprietary, the library may include sanitized versions of select information. The goal is to allow an analyst to have sufficient information to see if the analysis is relevant as a template for a new analysis being performed. In practice, the first three pieces of information—system or facility, DSHA, and task analysis—are those most readily and frequently captured in the library.

IV. LESSONS LEARNED FROM CATALOGING HISTORIC ANALYSES

Seven existing HRAs from the Norwegian oil and gas industry were provided for review and identification of issues. As noted, the task analysis library has nine aspects of the HRA to capture the relevant details of the analysis that can be reused in similar HRAs and support new analysis through archived documentation. In this section, we briefly review the findings from populating the task library with these seven historic analyses. The seven analyses are also summarized in Table I.

TABLE I. Match of information in existing HRAs to the task library elements

Task Library Element	**Facility A**	**Facility B**	**Facility C**	**Facility D**	**Facility E**	**Facility F**	**Facility G**
1. *A clear description of the type of systems and installations*	✖	✖	✖	✖	✖	✖	✖
2. *A description of DSHAs in the analysis*	✔	✔	✔	✖	✔	✔	✔
3. *A listing of the human failure events*	✔	✔	✔	✖	✔	✖	✖
4. *Links to the task analysis and human error identification*	✔	✔	✖	✔	✔	✖	✖
5. *Links to event and fault trees*	✖	✖	✖	✔	✖	✖	✖
6. *Links to the quantification worksheets*	✔	✔	✔	✔	✔	✖	✔
7. *A lessons learned synopsis*	✔	✔	✖	✖	✔	✖	✔
8. *Links to source documents that supported the analysis*	✔	✖	✔	✔	✔	✔	✔
9. *Other analyses that have made use of this information.*	✖	✖	✖	✖	✖	✖	✖

✔ denotes sufficient inclusion in the HRA
✖ denotes insufficient inclusion in the HRA

All seven HRAs mentioned the process applied across different phases and steps of the analysis, the data inputs, and key analysis assumptions. However, expectedly due to the legacy nature of the HRAs, many of the steps from the Petro-HRA guidleline[2] were incomplete or missing. It seems that the purpose of HRA was well understood, but the reports sometimes failed to execute a full, proper identification of tasks and the context of the problem at the installation. Several of the HRAs were performed in isolation of a probabilistic risk assessment, and the purpose mainly served to identify human factors issues to be addressed in the design of the system. The mismatch between the level of decomposition in the analysis and the needed level for proper quantification of the human failure event has been documented previously.[9]

Many HRAs were missing a sufficient description of what type of systems and installations were analyzed. Information about an existing installation, including its technology and operations, is required to collect all background information to define the problem at specific systems and installations. Also the descriptions of DSHAs that are implicated in the analysis were presented by all reports for further analysis, but the provided information did not have a lot of details and explanations. Documentation is a continuous process, and the lack of information creates a gap that might be carried throughout the analysis and precludes the opportunity for reuse later. Analysts had to define and analyze the human failure events to establish accident scenarios to represent the overall risk model. Depending on how well human failure events were defined earlier in the analysis, the process of defining and describing the scenarios can turn quite difficult since the scenario definition also shapes the subsequent qualitative and quantitative analyses. Following and completing the HRA steps in the Petro-HRA guideline can be beneficial for archiving the analysis for future use in new analyses.

Task analysis is another step in HRA, which describes the tasks performed during the scenario and steps underlying each task, time required to perform the task from the start to the finish, equipment used, roles and responsibilities, etc. The information is ideally collected and organized into a Hierarchical Task Analysis (HTA) or a Tabular Task Analysis (TTA) to later identify the sources of human error. If all of the task steps and sub steps are considered, potential errors related to the tasks will be identified during human error identification (HEI) as well as consequences and recovery opportunities, and also performance shaping factors (PSFs) that might have an impact on operator performance. The purpose of task analysis and HEI is to identify task failures, causes, consequences and recoveries. However, not every report was able to provide and link a complete task analysis and HEI for each human failure event that was listed and described in earlier steps of the HRA. Both detailed visual representations of HTA and TTA can be used for HEI. Missing or incomplete task analysis reduces the understanding of the operator tasks and limits the ability to reuse information.

Several of the available HRAs lacked or had incomplete sections on modeling. Fault tree analysis (FTA) and event tree analysis (ETA) are used to model human activities to show the interaction of the HRA in the overall probabilistic safety assessment. FTA and ETA are detailed representations of the errors and tasks and links errors with events. Without such modeling in the historic HRAs, there is no representation of how combinations of human errors and contributions to risk can cause undesired events. Modeling helps the analyst to find which errors matter the most and have the highest consequences and how they interact between each other. It also enables further human error quantification.

Some of the HRAs did not provide any suggestions or recommendations on how to reduce risk. One of the purposes of HRA is error reduction, improvement of safety of the system performance, and implementation of solutions. Error reduction analysis is used to recommend error reduction measures and suggest error reduction strategies across tasks and accident scenarios. Analysts can point out the major factors and systems that can be potentially improved to reduce human error probabilities and reduce the risk of undesired events.

After reviewing available HRAs it was identified that several of the analyses were lacking one or several key pieces of information. This creates gaps in knowledge about operator tasks and interactions between the system and operator. The task library captures analysis details for the purpose and ease of reuse in similar HRAs. To construct a quality HRA, analysts are required to collect documentation that can consist of background information, workshop results, and assumptions. Unfortunately, many analyses are hard to understand and follow, and impossible to reconstruct and adapt to meet the needs of the other facilities or installations. While the purpose of the task library is not to validate the Petro-HRA method, there is clearly a need for a consistent analysis process and documentation such as found in the Petro-HRA method. Having a standard method lends itself to archiving the findings and reusing them for future analyses.

V. LIBRARY PLATFORM

The Petro-HRA library is built using Microsoft OneNote, a software resource for sharing and cataloguing information. OneNote is the combination of a database (e.g., Microsoft SQL Server), a shared directory (e.g., Microsoft SharePoint), and an easy-to-use configuration management system (e.g., Microsoft Excel). It is included with Microsoft Office and is therefore a readily available resource for analysts. It is cross-platform, allowing it to be used by most computer users. It retains strict user access privileges, allowing information to be safely stored on a server—a particular concern due to the proprietary nature of HRA information. Additionally, access may be tiered, allowing certain users only to see certain non-proprietary information, while other users with proper credentials may access the entire collection of records. Finally, OneNote includes powerful built-in search tools, allowing analysts to find required information quickly yet in an organized fashion. A particular strength of OneNote is that as a native Microsoft Office application, it understands most common document formats and indexes them. Thus, searches, if desired, may not only reference the key indices of the library but may also reference the source documents embedded in the library.

The OneNote Petro-HRA library template serves multiple purposes. It is:

- A software guide for conducting new HRAs,
- An iterative data collection and knowledge management tool,
- A library of historical analyses that may not conform to the current Petro-HRA guidance but are nonetheless useful reference points, and
- A complete documentation of the Petro-HRA process including collecting of the metadata (emails, meeting notes, data collection, computations, guidance, etc.) associated with each Petro-HRA analysis.

Upon closure of the report, the entire OneNote can be archived in a "read only" OneNote format (allowing ease of reuse) with live hyperlinks, or as an Adobe Acrobat Personal Document Format (PDF) file that also supports live hyperlinks and may be easily shared. Either format can easily be dispositioned in a library (e.g., SharePoint website) that serves as a repository of information that can used for future HRA work. Specifically, documentation in the form of background information, workshop results, and assumptions that were made are crucial to understanding the HRA in the library and are captured in the tool iteratively by the analyst and the analysis team. In the past, the HRA community has been challenged in producing analyses that are standalone and oftentimes impossible to reconstruct. This OneNote structure in the form of a reusable template aims to provide consistency in method, data collection, and analysis with a promise of consistency often lacking in the HRA field. The OneNote Petro-HRA template should reduce or eliminate analysis shorthands and ensure that all artefacts (e.g., metadata) of the analysis are retained in their original form.

The OneNote Petro-HRA template also serves another vital function—the ability to reuse collected data for future HRAs. The analyst assigned to complete a new HRA is able to adapt past HRAs to the analysis to meet the needs of another facility or installation. With the iterative collection of data and stepwise analysis presented in the OneNote Petro-HRA template structure, the analyst is able to easily adapt this information for reuse, thus reducing the level of effort needed to produce the new analysis. For example, the OneNote structure easily allows the analyst to identify and comprehend the assumptions made by the previous analysts and compare them to new assumptions and update this existing information to fit the new analysis based on its context. The OneNote tool also allows the analyst to copy pages and or sections of past reports for reuse and modification to fit this new context, greatly reducing the level of effort and time required to produce a report.

The Petro-HRA library template in OneNote assists the analyst by simplifying the process of data collection and analysis, creating consistency in method application, and providing a means to archive the report and supporting information. This template also enables the analyst in the future to:

- Review past analyses including those that do not conform to current Petro-HRA guidance,
- Reuse past analyses,
- Provide for a means to easily collaborate with team members locally or remotely, and
- Provide HRA analysts an “iterative knowledge management tool” (capture knowledge as it is created).

It is important to note that although the current task library is implemented in OneNote, the purpose of this discussion is not to serve as advertisement for that software solution. Most of the functionality described here can be readily implemented on other platforms. OneNote simply serves as a convenient software platform for implementation of the task library.

VI. CONCLUSIONS

The Petro-HRA task library serves a twofold purpose—to capture HRAs and to guide the process of completing an HRA according the Petro-HRA method. The library serves as a repository of information that should be included with any quality HRA. Specifically, documentation in the form of background information, workshop results, and assumptions that were made are crucial to understanding the HRA in the library. Many analyses fail to be standalone—they represent a shorthand that is difficult to understand and perhaps impossible to reconstruct later. The library aims to prevent HRA shorthand and instead ensure that all artefacts, products, and assumptions of the analysis are retained.

Such information is crucial if an analyst reuses the HRA at a later date. Reuse is actually a misnomer. Reuse does not mean simply copying the contents of an existing analysis verbatim. Rather, reuse means adapting the analysis to meet the needs of another facility or installation. Adaptation of an existing HRA means understanding all the assumptions that were made, because those assumptions may not hold true for a new application. For example, tasks that were excluded because they were not risk significant in one context may prove highly significant in another context. Adaptive reuse requires that parts of the HRA be reanalyzed with updated information to fit the new application. The Petro-HRA task library can help this reuse process by ensuring consistent and thorough documentation of the HRA. Should there be a need to revisit an HRA, having comprehensive documentation is the key to reuse. The Petro-HRA task library seeks to ensure new analyses meet documentation expectations. Simultaneously, the Petro-HRA task library serves to capture as much meaningful information as possible from legacy HRA, thereby ensuring that relevant insights can usefully shape newer analyses.

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