Petro-HRA

Analysis of human actions as barriers in major accidents in the petroleum industry

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Background

• HRA in the nuclear industry
  – Long history of HRA, going back to early 1960s
  – HRA used as input to PRA/PSA

• QRA in the petroleum industry
  – Differences in how human & organization factors are represented in QRA
  – Maybe due to lack of suitable (i.e. non-nuclear) HRA methods?
Glossary

- HRA – Human Reliability Analysis
- QRA – Quantitative Risk Assessment
- PRA – Probabilistic Risk Assessment
- PSA – Probabilistic Safety Assessment
- HFE – Human Failure Event
- HEP – Human Error Probability
- PSF – Performance Shaping Factor
The Petro-HRA Project

• Established in 2012
• Main goal was to evaluate and adapt a nuclear HRA method to a petroleum context
  – SPAR-H chosen based on previous study which concluded that it was the most promising for evaluating petroleum events
Development of the Petro-HRA Method

• Much of the focus was on:
  – Evaluating and adapting SPAR-H nominal values and PSF descriptions & levels, to make them more suitable for petroleum activities & tasks
  – Documenting the qualitative analysis process, including task and error analysis, to make Petro-HRA a “complete” method

• Many HRA methods do not describe how to do qualitative analysis
  – Causes uncertainty amongst less experienced analysts
  – Increases variability between analysts in their approach and results

• Petro-HRA includes the qualitative part, “Complete” method
The Petro-HRA Method

- 7 steps in the method
- Non-linear – iteration between & within steps
- May include inputs from the QRA in the form of a HFE, HEP and/or scenario information
- Outputs an updated HEP to the QRA
- Outputs recommendations for improvement measures to the installation itself
The Petro-HRA Method

Qualitative Petro-HRA
Step 1: Scenario Definition

Inputs/Outputs

The Petro-HRA Method

1. Scenario definition
2. Qualitative data collection
3. Task analysis
4. Human error identification
5. Human error modeling
6. Human error quantification
7. Human error reduction
Step 1: Scenario Definition

• **Aim:** To define the scenario that is to be analysed and set the scope for the HRA

_**In your experience, what is the best source of information for developing the scenario description? Why?**_
Define the Scenario

- Scenario definition
  - Initial meetings
  - Document review
  - Scenario description

- QRA kick-off meeting
- General HAZID meeting
- HRA kick-off meeting
- Scenario meeting
- QRA reports
- Operating manuals / procedures
- Previous analyses (HRA, HF, Safety, etc.)
- HAZID / HAZOP reports
- Incident / Event reports
- Operational experience reports
Develop the Scenario Description

**Initial meetings**

- Document review

- Scenario description

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
<th>ACTIONS</th>
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<tbody>
<tr>
<td><strong>Location and external environment</strong></td>
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<td>Location of event</td>
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<td>External environmental conditions</td>
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<td><strong>System and task context</strong></td>
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<td>Operational mode</td>
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<td>Safety system / barriers</td>
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<td>Personnel roles and responsibilities</td>
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<td><strong>Event sequence and duration</strong></td>
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<td>End of event sequence</td>
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<td><strong>Timescale</strong></td>
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<td>Duration of event</td>
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Initial Task Identification

Basic behavioral model:
- Detect
- Diagnose
- Decide
- Act

Task goal:
1. Detect event
2. Diagnose event
3. Decide on actions
4. Execute actions

Event sequence and duration:
- Location and external environment
  - Location of event
  - External environmental conditions
- System and task context
  - Operational mode
  - Safety system / barriers
  - Personal roles and responsibilities
- Event sequence and duration
  - Initiating event
  - Intermediate events
  - End of event sequence
  - Timescale
  - Duration of event
Step 2: Qualitative Data Collection

Inputs/Outputs

The Petro-HRA Method

1. Scenario definition
2. Qualitative data collection
3. Task analysis
4. Human error identification
5. Human error modeling
6. Human error quantification
7. Human error reduction
Step 2: Qualitative Data Collection

• **Aim:** to better understand the operator tasks, possible errors, and performance shaping factors, *i.e. build a more detailed picture*

**In your experience, what is the best forum for collecting qualitative data?**
Collect Qualitative Data

Scenario description → Qualitative data collection

- Scenario walk/talk through
- Task/training observations
- Interviews/Discussions with operators

Detailed task information

Sequence of events & tasks
Timeline of events & tasks
Possible errors that could occur
Consequences of errors
Performance Shaping Factors
Collect Qualitative Data

Scenario talk-through / walk-through
- This should be one of the first activities in the data collection
- Gain a detailed understanding of how the operator would respond in the scenario
- Understand local contexts and constraints that could affect operator response

Observations of Task Performance / Training
- Understand how the operators work and interact with each other and the I&C systems around them
- Observe normal working conditions to collect general qualitative data
- Observe training exercise to collect scenario-specific qualitative data

Interviews / Discussions with Operators
- Most commonly used data collection technique
- Should always interview more than one operators to ensure a more balanced view
- Also consider interviewing shift managers, trainers, site QRA analyst/end user, HSE advisor, etc.
Talk About Human Error

• A common challenge for HRA analysts
  – This can be a sensitive subject, especially if there is a history of similar events at the installation
  – There may be high expectations of success in the scenario, and an unwillingness to admit things could go wrong
  – There may be a mindset of “that would never happen here”

• The analyst should:
  – Try to make the operator feel comfortable
  – Avoid directly asking what errors the operator could make
  – Instead ask “what could go wrong to prevent you from completing this task successfully?” or “what could happen if a less experienced operator was in this situation?”
  – Read event reports before interviews to be more familiar with error types, relevant terminology, etc.
Conduct a Timeline Analysis

- Time is often a critical factor in petroleum events; operators often have only minutes, or even seconds, to respond and intervene to control and mitigate the consequences of an event.
- Operators and other SMEs can give good insights into the time required to complete tasks, which tasks can be performed in parallel, where time pressure might exist, etc.
Identify Deviation Scenarios

- Deviations to the main scenario might also exist, and should be considered for analysis

  - A scenario that deviates from the nominal conditions normally assumed for the QRA sequence of interest, which might cause problems or lead to misunderstandings for the operating crews (adapted from Forester et al., 2007)

  - Deviations from what is generally expected, if sufficiently difference, can cause serious mismatches between the actual situation and the operators expectations, their performance aids, their usual approach to implementing procedures, and so forth (from Forester et al., 2007)
Step 3: Task Analysis

Inputs/Outputs

The Petro-HRA Method

1. Scenario definition
2. Qualitative data collection
3. Task analysis
4. Human error identification
5. Human error modeling
6. Human error quantification
7. Human error reduction

QRA

HEE

QRA

Rec's

Installation
Step 3: Task Analysis

• **Aim:** to understand the activities that are being analysed and to translate these details into the level of detail suitable for the HRA and the QRA.

**In your experience, what are the main uses of the task analysis in an HRA?**
Develop the Task Analysis

- Scenario description
- Qualitative information

Task Analysis

- Hierarchical Task Analysis
- Tabular Task Analysis
- Detailed task descriptions
Hierarchical Task Analysis

- Main challenge is to determine the appropriate level of decomposition
  - Level of decomposition should be matched to the purpose of the analysis & to enable error identification & PSF evaluation
  - Not all task steps need to be decomposed to the same level – focus on those critical to the overall analysis
Tabular Task Analysis

<table>
<thead>
<tr>
<th></th>
<th>Step No.</th>
<th>Description</th>
<th>Cue / Feedback</th>
<th>Procedure</th>
<th>HMI</th>
<th>Person Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>Manually activate blowdown</td>
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<td>3</td>
<td>1</td>
<td>Detect leakage</td>
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<tr>
<td>4</td>
<td>1.1</td>
<td>Detect audio alarms</td>
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<tr>
<td>5</td>
<td>1.2</td>
<td>Detect visual alarms</td>
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<tr>
<td>6</td>
<td>2</td>
<td>Diagnose event</td>
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<td>7</td>
<td>2.1</td>
<td>Examine leakage location</td>
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<td>8</td>
<td>2.2</td>
<td>Examine leakage size</td>
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</tbody>
</table>

• Extends the HTA to include more detailed information about the tasks
• The exact content of the TTA may vary from HRA to HRA, depending on the scope and needs of the analysis; e.g.
  – A critical task may be diagnosis of the event from the alarm screen, and so the TTA may be more focused on how operators use the HMI, rather than e.g. tasks outside the control room; or
  – A critical task may be the location and manipulation of a particular valve by a field operator, and so the TTA may be more focused on the work environment, access to the valve location, etc.

• Remember to include any assumptions or uncertainties about the task steps in the TTA
Step 4: Human Error Identification

Inputs/Outputs

- QRA

The Petro-HRA Method

1. Scenario definition
2. Qualitative data collection
3. Task analysis
4. Human error identification
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6. Human error quantification
7. Human error reduction

The arrows indicate the flow of information or the sequence of steps in the process.
Step 4: Human Error Identification

• **Aim:** to identify and describe potential errors that could occur in the scenario as well as the consequences and possibilities for recovery of these errors, and to identify and describe the performance shaping factors that could impact on error probability.

**In your experience, what difficulties might the analyst encounter when trying to identify and describe potential errors?**
Identify and Describe Errors

Task Analysis → Human Error Identification

- Identify errors
- Identify consequences
- Identify recovery opportunities
- Identify PSFs

Updated TTA

Analyst judgment
Error taxonomy

Petro-HRA PSF descriptions
Identify Human Errors

• Two main ways to identify errors:
  1. Identify the “obvious” errors. E.g. if the task step is “detect visual alarms” then the obvious error is that the operator does not detect the visual alarms
  2. Use the extended list of SHERPA guidewords to prompt error identification

<table>
<thead>
<tr>
<th>Action Errors</th>
<th>Checking Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1-Operation too long/short</td>
<td>C1-Check omitted</td>
</tr>
<tr>
<td>A2-Operation mistimed</td>
<td>C2-Check incomplete</td>
</tr>
<tr>
<td>A3-Operation in wrong direction</td>
<td>C3-Right check on wrong object</td>
</tr>
<tr>
<td>A4-Operation too little/much</td>
<td>C4-Wrong check on right object</td>
</tr>
<tr>
<td>A5-Misalign</td>
<td>C5-Check mistimed</td>
</tr>
<tr>
<td>A6-Right operation on wrong object</td>
<td>C6-Wrong check on wrong object</td>
</tr>
<tr>
<td>A7-Wrong operation on right object</td>
<td></td>
</tr>
<tr>
<td>A8-Operation omitted</td>
<td>Retrieval Errors</td>
</tr>
<tr>
<td>A9-Operation incomplete</td>
<td>R1-Information not obtained</td>
</tr>
<tr>
<td>A10-Wrong operation on wrong object</td>
<td>R2-Wrong information obtained</td>
</tr>
<tr>
<td>Information Communication Errors</td>
<td>R3-Information retrieval incomplete</td>
</tr>
<tr>
<td>H1-Information not communicated</td>
<td>Selection Errors</td>
</tr>
<tr>
<td>I2-Wrong information communicated</td>
<td>S1-Selection omitted</td>
</tr>
<tr>
<td>I3-Wrong information communicated incomplete</td>
<td>S2-Selection made</td>
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<tr>
<td>D1-Correct decision based on wrong/missing information</td>
<td>Decision Errors</td>
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<tr>
<td>D2-Incorrect decision based on right information</td>
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<tr>
<td>D3-Incorrect decision based on wrong/missing information</td>
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<tr>
<td>D4-Failure to make a decision (impasse)</td>
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</tbody>
</table>
Identify Error Consequences

• Error consequences should be specific, to allow for later screening and modeling
  – What is the immediate consequence of the error?
  – What is the long-term consequence?
  – Does the consequence have an effect on subsequent task steps?
  – Does the consequence have an effect on how the event escalates?
Identify Recovery Opportunities

• The analyst should consider whether and how the operator could recover from the error, and what effect this has on the scenario:
  – Could the operator immediately identify that they have done something wrong, e.g. through a subsequent task step or system intervention?
  – Could the operator identify and recover from the error later in the task, e.g. as a result of a peer check?
  – Could the operator fail to recover from the error as there is no subsequent cue for the operator to check, and no interlocks to prevent further incorrect actions?
Update the TTA

- The TTA should be extended to include information about errors, consequences and recovery alongside the relevant task steps.

<table>
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<tr>
<th>Step No.</th>
<th>Description</th>
<th>Cue / Feedback</th>
<th>Procedure</th>
<th>HMI</th>
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<th>Consequence</th>
<th>Recovery Opportunities</th>
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Identify Performance Shaping Factors

- The Petro-HRA method quantifies errors by considering the effects of PSFs.
- Therefore the analyst must also consider what PSFs exist that may contribute to the identified errors by considering “what if...?”, e.g.
  - Is time a factor for the error potential in this task?
  - Could the quality of procedures affect the potential errors in this task?

- The Petro-HRA method includes nine PSFs:
  1. Time
  2. Threat Stress
  3. Task Complexity
  4. Experience / Training
  5. Procedures
  6. Human-Machine Interface
  7. Adequacy of Organization
  8. Teamwork
  9. Physical Working Environment
Update the TTA

- The TTA should be extended again to include information about the identified PSFs alongside the relevant task steps.

<table>
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<tr>
<th>Step No.</th>
<th>Description</th>
<th>Cue / Feedback</th>
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<th>Potential Error</th>
<th>Consequence</th>
<th>Recovery Opportunities</th>
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Step 5: Human Error Modeling

Inputs/Outputs

The Petro-HRA Method

1. Scenario definition
2. Qualitative data collection
3. Task analysis
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6. Human error quantification
7. Human error reduction

QRA

HFE

QRA

HEP

Installation

Rec's
Step 5: Human Error Modeling

• **Aim:** to clarify and demonstrate the links between the identified human errors, task steps, PSFs and the overall HFE.

What is your preferred method for human error modeling? Why?
Human Error Modelling

• Two main approaches used in HRA:
  – Event Tree Analysis
  – Fault Tree Analysis

• Event trees most commonly used in QRA, and therefore it is the recommended approach for Petro-HRA
  – Event trees provide a good high-level description of the post-initiating event scenario
  – It may be easier to integrate the results into the QRA event tree if a similar format is used
Develop an Event Tree

```
<table>
<thead>
<tr>
<th>Initiating event</th>
<th>Detect leakage</th>
<th>Diagnose event</th>
<th>Decide on blowdown</th>
<th>Activate blowdown</th>
<th>Final outcome / end state</th>
</tr>
</thead>
</table>
```

- **Initiating event:**
  - **Detect leakage:**
    - **Diagnose event:**
      - **Decide on blowdown:**
        - **Activate blowdown:**
          - **Final outcome / end state:**
            - Yes: Success
            - No:
              - End state 4
              - End state 3
              - End state 2
              - End state 1
```