Petro-HRA

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

Andreas Bye, Karin Laumann, Claire Taylor, Martin Rasmussen, Sondre Øie,
Koen van de Merwe, Knut Øien, Ronald Boring, Nicola Paltrinieri,
Irene Wærø, Salvatore Massaiu, Kristian Gould

Human Factors in Control, 27 April 2016

Contents

Overview of the Petro-HRA Method
• Background
• The Petro-HRA Project
• Development of the Petro-HRA Method
• The Petro-HRA Method including case examples
  – Qualitative
  – Quantitative
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

Qualitative Petro-HRA
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

Develop the Scenario Description

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>DESCRIPTION</th>
<th>COMMENTS</th>
<th>ACTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location and external environment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Location of event</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External environmental conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System and task context</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational mode</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety system / barriers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personnel roles and responsibilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Event sequence and duration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initiating event</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate events</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of event sequence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timescale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of event</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Scenario example – DP drive off

Scenario analysis table

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiating event</td>
<td>Unforeseen DP failure initiates the drive-off. All thrusters pointing aft -</td>
<td>It is not important to define the actual cause (i.e., failure mode) of the</td>
</tr>
<tr>
<td></td>
<td>giving forward thrust. Thrusters are at zero resolution giving zero forward</td>
<td>drive-off. This is because the source patterns and required actions will</td>
</tr>
<tr>
<td></td>
<td>thrust at the starting point. Error in the DP control initiates the thrusters</td>
<td>more or less be the same. For more than 4 thrusters, calculations show</td>
</tr>
<tr>
<td></td>
<td>to accelerate up to full forward thrust. 4 thrusters running in calm water.</td>
<td>that the scenario duration reported below is too long and the automatic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>is required to activate before the DPO activates the manual EDS.</td>
</tr>
<tr>
<td>Intermediate events</td>
<td>Operator:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Detect drive-off</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Diagnose the situation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Decide the next steps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Activate emergency thruster stop (bringing the rig into a drift-off)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Activate the Red Alert and EOS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of event sequence (successful)</td>
<td>Successful manual shutdown of the thrusters followed by manual activation</td>
<td>There is no direct feedback in the system for successful disconnection</td>
</tr>
<tr>
<td></td>
<td>(successful)</td>
<td>of the EDS results in a timely and safe disconnection of the URRF from</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the BOP.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of event sequence</td>
<td>For this scenario the Automatic EDS is enabled with a safety margin to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>prevent damage to the well and rig.</td>
</tr>
</tbody>
</table>
Initial Task Identification

Event → \[\text{Basic behavioral model}\] → Task goal

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

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

QRA → HFE → 8. Human error quantification

QRA → HEP → 7. Human error reduction

Installation → Rec's
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 operator 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.
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
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

HTA example

PetroHRA
Tabular Task Analysis

- 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

TTA example

<table>
<thead>
<tr>
<th>Step No</th>
<th>Task</th>
<th>Cue / Feedback</th>
<th>Procedure</th>
<th>HMI</th>
<th>Person Responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Check rior angle</td>
<td>Noticeable increase in rior angle displayed in degrees.</td>
<td>DPO 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>Check rior speed</td>
<td>Noticeable increase in speed on HMI displayed in knots.</td>
<td>K-Pax - DPO 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td>Check position offset</td>
<td>Noticeable position offset on well displayed in meters and with a rior position diagram.</td>
<td>K-Pax - DPO 1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10.1 TTA for the task “Diagnose drive-off event”
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.

Timeline analysis example
Timeline analysis table example

Table 10.1 Timeline analysis table for the task “Diagnosis drive-off event”

<table>
<thead>
<tr>
<th>Task step</th>
<th>Step times and duration</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>XX seconds after noticing increased throttle rev and sound, at Time=XX seconds, the DPO starts diagnosing the event by checking motor angle, rpm speed, and position offset.</td>
<td>In the workshop it was argued that XX seconds for diagnosis is a conservative estimate.</td>
</tr>
<tr>
<td>5.</td>
<td>Realizing that the ng is in a degraded situation, the DPO switches to yellow status at Time=XX seconds. At this time it would also be natural to dial on the second DPO for support.</td>
<td>Recommendation: The priority of switching to yellow status during this scenario should be evaluated in terms of criticality (consequence of omitting this step) against the added complexity of the task by having yet another action to recall. This could be compared against only having to switch to red status before shutting down thusters and activating EDS.</td>
</tr>
<tr>
<td>6.</td>
<td>XX to YY seconds is required to confirm drive-off by iteratively examine trends of various parameters, making the diagnosis last approximately Time=XX to YY seconds.</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>The last XX seconds of performing the diagnosis, the DPO(s) start deciding on how to act.</td>
<td></td>
</tr>
</tbody>
</table>

Step 4: Human Error Identification

![Diagram of the Petro-HRA Method]

The Petro-HRA Method:

- 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
- 8. Human error quantification
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

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?

HEI example

Table 10.2 Human error identification for the task “Diagnose drive-off event”

<table>
<thead>
<tr>
<th>Step No</th>
<th>Description</th>
<th>Potential error</th>
<th>Likely consequences</th>
<th>Recovery opportunity</th>
<th>Further analysis</th>
<th>PAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>DIAGNOSE DRIVE-OFF EVENT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Check riser angle</td>
<td>DPO omits to check riser angle</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DPO misidentifies riser angle (degree is less than actual)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DPO checks riser angle too late or spends too much time checking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Update the TTA

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

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Description</th>
<th>Con / Feedback</th>
<th>Procedure</th>
<th>HUI</th>
<th>Person Responsible</th>
<th>Potential Error</th>
<th>Consequence</th>
<th>Recovery Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Manually activate blowdown</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Detect leakage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 1.1</td>
<td>Detect audio alarms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 1.2</td>
<td>Detect visual alarms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Stop event</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 2.1</td>
<td>Examine leak site</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 2.2</td>
<td>Examine leak site</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

Step 5: Human Error Modeling
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

Event tree table

<table>
<thead>
<tr>
<th>ID</th>
<th>Event</th>
<th>Failure Event</th>
<th>Potential errors (from HEI)</th>
<th>HEC</th>
<th>Final outcome/End state</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DPO detects DP abnormalities. Ref. Task 1.0</td>
<td>_failure to detect DP abnormalities. The drive-off is not detected or detected too late by the DPO, making him or her unaware of the drive-off being initiated.</td>
<td>DPO does not hear sound of thrusters increasing (or too late). DPO does not detect increase in thruster force on HMI. DPO does not hear sound of thrusters increasing. DPO does not detect increase in thruster force on HMI.</td>
<td>0.x</td>
<td>The Automatic EOS is activated according to the offset position limit defined in the WSCC. Due to the speed of the rig, the failure of the controller may be too slow for the disconnection to be successful. Damage or breakdown of equipment, with potential environmental impact (e.g. spill of mud)</td>
</tr>
<tr>
<td>2</td>
<td>DPO diagnoses situation as drive-off. Ref. Task 2.0</td>
<td>Failure to diagnose drive-off. The DPO does not realize that the abnormalities indicate a drive-off (as described in the scenario description). For example, he or she fails to recognize the type of event or its severity.</td>
<td>DPO does not diagnose that this is a drive-off event. See additional associated human errors marked (Y) in the HEI Table 11.3.</td>
<td>0.x</td>
<td>See ID 1 (above).</td>
</tr>
<tr>
<td>3</td>
<td>DPO decides to disconnect rig from well.</td>
<td>Failure to decide on correct mitigating actions.</td>
<td>DPO does not realize that thrusters should be stopped first before initiating EOS.</td>
<td>0.x</td>
<td>See ID 1 (above).</td>
</tr>
</tbody>
</table>
Event tree table cont.

<table>
<thead>
<tr>
<th>ID</th>
<th>Event</th>
<th>Failure Event</th>
<th>Potential errors (from HSE)</th>
<th>HSE</th>
<th>Final outcome/Final state</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Ref Task 3.0</td>
<td>The DPO decides not to stop thrusters and/or disconnect, fails to make a decision in time, decides to attempt a different recovery (e.g. regain position), or 'freezes' due to stress.</td>
<td>Decision to stop thrusters takes too long.</td>
<td>DPO decides not to initiate EDS. Decision to initiate EDS takes too long.</td>
<td>0 x see ID 1 above. For partial or delayed stop of the thrusters, damage can be less than if the thrusters are not stopped at all.</td>
</tr>
<tr>
<td>4</td>
<td>DPO stops all running thrusters. Ref Task 4.2 Ref Task 4.4</td>
<td>Failure to stop all running thrusters. The DPO fails to stop all running thrusters at all, too late, or partially.</td>
<td>DPO takes too long to press the buttons for all active thrusters. DPO stops the wrong thrusters (i.e. the wrong 6 out of 8). DPO does not confirm that all active thrusters have stopped.</td>
<td>0 x Assuming that the Automatic EDS is enabled and that the DPO stops the thrusters in a timely manner, there will be no impacts associated with this event.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>DPO activates emergency disconnect seq.</td>
<td>Failure to activate emergency disconnect sequence (EDS). The DPO fails to activate EDS at all or in time before the Automatic EDS is activated.</td>
<td>DPO does not press EDS buttons. DPO takes too long to press EDS buttons.</td>
<td>0 x</td>
<td></td>
</tr>
</tbody>
</table>

PetroHRA Quantification

How to, when to, where to, who should and why quantify

Martin Rasmussen
HFC
27.04.16 Oslo
My role in PetroHRA

- The Ph.D. Candidate (submitted jan 16)
- From a psychology background
- Mainly focused on quantification

- 1 PhD (hopefully accepted soon)
- 4 journal papers
- 10 conference papers

Approach to creating the quantification in PetroHRA

- Based on SPAR-H
- Interviews with HRA analysts to pinpoint problems
- Thematic analysis to determine content in PSFs and reduce overlap
- Evaluated both research and other HRA methods in the selection of values and multipliers
When to quantify
Where to quantify
How to quantify
Why quantify
Who should quantify
When to quantify

Where to quantify

How to quantify

Why quantify

Who should quantify
Where to quantify

• Same issues as in task analysis
  – What is the appropriate level of decomposition to quantify at?
    • If you quantify at a level too high you might loose important information
    • If you quantify at a level too low you might loose the big picture
    • Some PSFs are easier to include at a low level, others are easier at a high level.

Where do we quantify

• Findings from ESREL-paper: Does the granularity of the quantification matter?
  – It does, but no level is necessarily perfect for every occasion. There are pros and cons with any level
  – Major problems are likely to be found and dominate the analysis either way
  – SPAR-H leaves the choice to the analyst, is that the best approach? Or should a level be specified?

When to quantify
Where to quantify
How to quantify
Why quantify
Who should quantify
How to quantify

Nominal HEP \times \text{PSFs} \quad \text{with} \quad \text{PSF Levels} \quad = \quad \text{HEP}

- Time
- Threat Stress
- Task Complexity
- Experience/Training
- Procedures
- HMI
- Adequacy of Organization
- Teamwork
- Physical Working Environment

- Extremely High Negative
- Very High Negative
- High Negative
- Moderate Negative
- Low Negative
- No Effect
- Low Positive
- Moderate Positive

PetroHRA Quantification

Nominal HEP \times \text{PSFs} \quad \text{with} \quad \text{PSF Levels} \quad = \quad \text{HEP}

Differences from SPAR-H
<table>
<thead>
<tr>
<th>The Performance Shaping Factors</th>
<th>Effect of the Performance Shaping Factors</th>
<th>How it Affects Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Machine Interface</td>
<td>Stress</td>
<td>Reliability</td>
</tr>
<tr>
<td>Task Complexity</td>
<td>Time Pressure</td>
<td>Efficiency</td>
</tr>
<tr>
<td>Limited Time</td>
<td>Workload</td>
<td></td>
</tr>
<tr>
<td>Experience</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ergonomics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teamwork</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example PSF: HMI

**Definition:** The Human-Machine Interface (HMI) PSF refers to the quality of equipment, controls, hardware, software, monitor layout, and the physical workstation layout where the operator/crew receives information and carries out tasks.

**Examples:** Difficulties in obtaining relevant information or carrying out tasks through the safety and automation system, layout organization or colors that are not stereotypical, and communication difficulties due to communication technology (walkie-talkies, phones, messaging systems). In systems that use inter-page navigation it should be evaluated if it is likely that this will cause masking of relevant information or difficulties in carrying out a task due to several page shifts.

<table>
<thead>
<tr>
<th>50</th>
<th>Very high negative effect on performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>The HMI causes major problems in either obtaining relevant information or carrying out the task. For example, the HMI is not designed for the task leading to a difficult work-around, some of the relevant information required for a reliable decision is not made available or, the inter-page navigation creates severe difficulties in obtaining the relevant information or carrying out the task.</td>
</tr>
</tbody>
</table>
HMI

- Changed to only focus on HMI
  - Physical work environment included in a separate PSF.
- Large differences between the HMI in most US NPPs and O&G-industry
- The evaluation of whether the HMI impacts the performance of the operators is similar
- Probably even more important in a computerized/digital control room

Time

- In other methods included as: “Available time”, “Time Pressure”
- Time needs to be included
- Should it be as a PSF?
Time

- **Available time:** the time from the presentation of a cue for action to the time of adverse consequences if no action is taken.

- **Required time:** the time it takes for operators to successfully perform and complete a task.

- Input from the timeline analysis

Threat Stress

- Threat to:
  - Own life
  - Others lives
  - Self-esteem
  - Professional status
Task Complexity

- Replaces «Complexity»
- Focuses on the objective, not the subjective complexity
- We have attempted to reduce overlap


Experience/Training

- Focus on quality
  - Different from SPAR-H focus on time employed

Procedures

• Large industry differences in the extent of procedure use

• Important to remember that the evaluation is of the effect they have

Adequacy of Organization

• One of the two factors that replaces «Work Processes» from SPAR-H

• The PSF Adequacy of Organization consists of two related factors that have been found to predict safety outcomes in studies of safety culture:

  1) Attitudes to safety and work conduct,

  2) Management support.
Teamwork

• The other of the two factors that replaces «Work Processes» from SPAR-H
• Teamwork can have a very significant effect on performance
• Is very team/crew dependent, but factors that contribute to good or poor teamwork can be found.

Physical working environment

• Aka. «Ergonomics»
  – Changed name due to potential confusion
• Was included in the «HMI/Ergonomics» PSF in SPAR-H

• Included to ensure that non-HMI problems (such as those faced in ex-control room tasks are covered)
## Petro-HRA PSF summary worksheet

<table>
<thead>
<tr>
<th>PSFs</th>
<th>PSF levels</th>
<th>Multiplier</th>
<th>Substantiation. Specific reasons for selection of PSF level</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Available time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremely high negative</td>
<td>HEP=1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high negative</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate negative</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate positive</td>
<td>0.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not applicable</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Threat stress</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High negative</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low negative</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very low negative</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not applicable</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Task complexity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very high negative</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate negative</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very low negative</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### When to quantify
- **Where to quantify**
- **How to quantify**
- **Why quantify**
- **Who should quantify**
The remaining questions

- Why do we quantify? And what is the expected outcome?
  - Is it only to get an HEP?
  - Is it to red flag the most important issues?

- Who should quantify?
Error reduction

- Impact assessment
- Error reduction analysis

Impact assessment

- Integration of HEP into overall risk model
- Consideration of impact assessment criteria;
  - Risk acceptance criteria
  - Size of HEP value(s), >0.1
  - Degree of HEP uncertainty
  - Severe QRA end states
- Assessment of HEP contribution
Error reduction analysis

• Select events for risk reduction
• Re-visit performance shaping factors
• Develop ERMs targeting specific human errors
• Develop ERSs targeting overall task performance
• Recalculate HEPs based on updated PSF justifications

Select events for risk reduction

![Event tree](image)

Figure 7.2 Event tree with example quantifications

For event trees, events are selected based on three combined considerations:

1) the HEP for each single event
2) the HEP for end states associated with each event sequence pathway
3) the severity of end states for each event sequence pathway the events are part of

![PetroHRA](image)
Re-visit performance shaping factors

• Purpose is to demonstrate risk reduction
  – Establish traceability between the PSF evaluations, calculated HEPs and suggested ERM and/or ERSs
• Re-check which PSFs are performance drivers
• Error reduction measures (ERM) and strategies (ERS) can target other PSFs than the negative ones

Develop ERM & ERS

- Error mechanism prevention
- Error pathway blocking
- Error recovery enhancement
- Error consequence reduction

- Overall task re-design
- Overall PSF improvement

ERM

ERS
Update HRA/QRA model

HRA
• Document justifications (Petro-HRA sheet)
• Re-calculate HEPs for each event and model

QRA
• Integrate HFE HEP in QRA model
• Re-calculate QRA to check for effects

Document HRA
• All analysis outputs; ensure traceability
  – Scenario description
  – PSF assessment
  – Task and timeline analysis
  – Human error identification
  – Human error model, incl. summary table
  – Human error quantification, incl Petro-HRA sheets
  – Impact assessment and error reduction analysis