Defining and operationalizing the barrier concept

The human contribution

Sondre Øie
30 April 2013
Introduction

- Sondre Øie
  - Human Factors & risk management consultant at DNV

- Topics & focus in this presentation
  - What is a barrier?
  - Operationalization
  - The human contribution
  - Focus on Human Factors, less on organisation

- Inspired by
  - Risk and reliability techniques
  - Nuclear industry
  - Old and recent developments within O&G
  - Human Factors methods
  - Project experience within Safety Barrier Management
Barriers on Google

Wikipedia: A barrier or barricade is a physical structure which blocks or impedes something.

Source: www.herasreadyfence.co.uk
A simple example to understand the complexity
Operationalize the barrier concept

The need for operationalization....

From Wikipedia

- **Operationalization** is the process of defining a *fuzzy concept* so as to make the concept *clearly distinguishable* or *measurable* and to understand it in terms of empirical observations.

- In a wider sense it refers to the process of specifying the extension of a concept — describing what is and is not a part of that concept.

**Bold statement (?!): Barriers and barrier management is a *fuzzy concept***
The “fuzzy” concept

- Hazardous event
- Loss
- Risk
- Consequence
- Hazard
- Loss
- Risk
- Consequence
- Hazard

- Threat
- Initiating event
- HAZID
- Incident

- Triggering condition
- Incident
- HAZID
- Threat
- Initiating event

- Accident
- Barrier strategy

- Performance shaping factor
- Performance requirements
- Performance standards

- Failure modes
- Barrier degradation

- Barrier decay mechanisms
- Risk influencing factors
- Human Error
- Human Reliability
- Structural barriers
- Active barriers
- Operational barriers
- Technical barriers
- Organisational barriers

- Barrier system
- Barrier classification
- Barrier function
- Barriers

- Controls
- Defence
- Protection layer
- Bow-Tie

- HAZOP
- Swiss Cheese
- QRA

- Barrier element
- Barrier
- Barrier classification
- Barrier system

- Performance standards
- Failure modes

- Human Factors
- Risk influencing factors
- Barrier degradation

- Defining and operationalizing the barrier concept

30 April 2013
© Det Norske Veritas AS. All rights reserved.
Barrier definitions

BARRIERS

- **Barriers** can be defined as measures that are designed/implemented with the explicit purpose (1) to reduce the probability of triggering a pre-defined hazards (loss) potential and/or (2) to reduce the consequence of a pre-defined hazardous event (Skjerve et al. 2003).

- A **barrier** is a physical or engineered system or human action (often based on specific procedures or administrative controls) that is implemented to prevent, control, or impede energy released from reaching the assets and causing harm (Rausand, 2011).

NORSOK Z-013

- **Barrier function**: Function planned to prevent, control, or mitigate undesired or accidental events

- **Barrier system**: System designed and implemented to perform one or more barrier function

- **Barrier element**: Physical, technical or operational component in a barrier system
Barriers as functions, systems and elements

Illustration of how barrier systems and elements perform the main barrier function “prevent blowout”
Example: “Minimize Leakage” barrier functions

Other barrier functions:
- Prevent leakage
- (Minimize leakage)
- Avoid ignition
- Mitigate explosion
- Reduce fire load
- Avoid escalation
- Protect personnel

Functions marked with * may involve or depend on CCR operator tasks

Minimize leakage

1 Detect leakage
- 1.1 Detect external leakage
  - 1.1.1 Detect gas automatically in area
  - 1.1.2 Detect gas manually in area
  - 1.1.3 Monitor liquid level in process vessels
- 1.2 Detect internal leakage
  - 1.2.1 Monitor gas content in cooling/heating medium
  - 1.2.2 Monitor pressure in cooling/heating medium

2 Control input from source
- 2.1 Control production wells
- 2.2 Control upstream plants
- 2.3 Control upstream segments

3 Sectionalize process segments
- 3.1 Control sectionalizing valves (PSDV)
- 3.2 Control emergency shutdown valves (ESDV)

4 Ensure safe disposal of internal (gaseous) content
- 4.1 Control safe disposal of gaseous content
- 4.2 Control blowdown valves
- 4.3 Control release point

5 Ensure safe disposal of liquid content
- 5.1 Route releases to hazardous open drain
- 5.2 "Bund" to avoid unintentional spread to...

How?

Why?
### Mapping barrier functions, systems & elements (incl. tasks)

<table>
<thead>
<tr>
<th>#</th>
<th>Barrier functions</th>
<th>Description</th>
<th>Barrier systems/ elements</th>
<th>Operator tasks</th>
<th>Performance req.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function level</td>
<td>Name of functions, e.g.:</td>
<td>Purpose of function and how it performs, e.g.:</td>
<td>List of barrier systems and elements performing the function, e.g.:</td>
<td>Tasks necessary to perform barrier functions are mapped with regards to different operational modes, such as:</td>
<td>Barrier performance requirements, typically:</td>
</tr>
</tbody>
</table>
| 1.0 | o Prevent leakage  
|     | o Minimize leakage  
|     | o Avoid ignition  
|     | o Mitigate explosion  
|     | o Reduce fire load  
|     | o Avoid escalation  
|     | o Protect personnel  
|     | o Etc. | “In order to prevent escalation of abnormal conditions into a major hazardous...” | Emergency Shutdown  
|     | o ESD valves  
|     | o PSD valves  
|     | o ESD alarms  
|     | o Process HMI  
|     | o Manual push-button  
|     | o Etc. | o Normal operations  
|     | o Shutdown/ start-ups  
|     | o System upsets/ incidents | o Availability  
|     | o Functionality  
|     | o Reliability  
|     | o Robustness  
|     | o Integrity  
|     | o Etc. |

- The barrier function hierarchy can be listed in a table for obtaining more information about how barrier systems, elements and operator tasks interact to perform barrier functions.

- Provides traceability from operator tasks -> barrier elements -> barrier systems -> and main barrier function presented in risk models, such as Bow-Tie’s or Swiss Cheese

- Allows for barrier performance requirements to be reviewed on both detailed (element) and higher (system) levels
Human interaction with barriers

- Humans *primarily* interact with barriers in two ways;
  1. Monitoring tasks, control and activation of barriers
  2. Maintenance, testing and inspection of barriers

- Humans *reduce* risk by e.g.;
  - Discovering & correcting technical failures
  - Able to problem-solve and understand system status

- Humans *increase* risk by e.g.;
  - Introducing *“latent conditions”* such as incorrect maintenance
  - *“Unsafe acts”* initiating incidents, e.g. when working on pressurized HC piping or controlling barrier systems

- Human performance is influenced by *Performance Shaping Factors* (PSFs)
- PSFs affects *human reliability* and *human error* probability
Monitoring, control and activation of barriers

Simple sequential model of operator tasks necessary to perform a barrier function (iteration not shown)

Performance shaping factors

Driller detects a kick and presses one of the available pushbuttons to activate shear ram

PLC sets output signals according to drillers command

Signal from PLC closes the shear ram
Performance shaping factors (PSFs)

“External” PSFs
- Competence & training,
- Procedures & work processes,
- Function allocation & automation
- HMI & ergonomics,

“Experienced” PSFs
- Available time
- Workload & stress
- Task complexity

Task performance

Detection, diagnosis, decisions, actions

Barrier function
## Performance shaping factors vs barrier elements

<table>
<thead>
<tr>
<th>Examples</th>
<th>How PSFs may reduce risk of human error and increases human reliability</th>
<th>Common notions for why some PSFs are often considered “barrier elements”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competence, training</td>
<td>Ensures that operator is confident with task at hand, creates less stress, reduces complexity</td>
<td>Competence specifically targeting tasks related to barrier functions, e.g. handling a gas leak</td>
</tr>
<tr>
<td>HMI, alarm system</td>
<td>Facilitates situational awareness, supports diagnosis and decision making, incorporates human error tolerance</td>
<td>Is the direct link between the operator and the barrier system, e.g. allows control and monitoring of barrier functions</td>
</tr>
<tr>
<td>Procedures</td>
<td>Available and good procedures provides guidance and support on how to perform tasks</td>
<td>Gives directions, often based on system safety philosophies, on how and when to act</td>
</tr>
</tbody>
</table>
Inspection, testing and maintenance of barriers

It’s like plugging the “holes” in the Swiss Cheese model…
# Task analysis to establish performance requirements

<table>
<thead>
<tr>
<th>#</th>
<th>Task</th>
<th>Description</th>
<th>Performed by</th>
<th>Equipment and procedures</th>
<th>Performance requirements</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Manually activate blowdown</td>
<td>In case of a gas leakage the CCR operators receive an alarm. They then have to detect this alarm, make a diagnosis of the situation and decide whether and how to activate blowdown.</td>
<td>CCR operators (Field operator)</td>
<td>Visual display unit (HMI) on operator station.</td>
<td>The DSHA procedure shall support the operator in the blowdown sequence by clearly indicating steps, roles &amp; responsibilities in handling the situation etc.</td>
<td>Barrier function 3.2.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Emergency Response Team)</td>
<td>UHF radio to communicate with field operator.</td>
<td></td>
<td>Performance standards</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DSHA procedure from the Emergency Preparedness manual.</td>
<td></td>
<td>QRA/HRA</td>
</tr>
</tbody>
</table>

- Essentially a breakdown of tasks associated with barrier functions
- Provides overview and details about operations and actions
- Can be used to address requirements for PSFs, e.g. whether HMI supports specific tasks
- Input to other analysis (e.g. HRA)

**Explanations:**

- #: Task number,
- Task: Name of task identified in the barrier function analysis
- Description: Description of task in more detail
- Performed by: Who is directly/(indirectly) involved in performing the tasks
- Equipment and procedures: What the operator(s) use while performing the task (often referred to as barrier elements)
- Performance requirements: Requirements for Performance Shaping Factors, minimizing the risk of human error and increases human reliability. Requirements are set for procedures, HMI, competence, work processes etc.
- References: References to barrier functions and relevant documentation
Relevant techniques and methods

- **Human Factors Engineering**
  - Task analysis to capture system requirements necessary to ensure a human-centred design
  - HMI and alarm reviews to provide situational awareness and error tolerance
  - CRIOP to verify and validate Control Centres’ ability to handle incidents

- **Risk assessments**
  - Human Error Analysis (qualitative) to identify error modes and eliminate error traps – similar to FMECAs for technical systems
  - Human Reliability Analysis (quantitative) to assess how human error probability is influenced by performance shaping factors – often combined with QRAs, LOPAs

- **Safety analysis**
  - Safety Critical Task Analysis to identify critical maintenance tasks vulnerable for introducing latent error conditions

- **Training**
  - Crew Resource Management (CRM) to train operator crews in teamwork skills facilitating early identification of threats and errors, so incidents can be avoided at early stages
  - Competence development within major accident risk understanding and barriers
### Summary

- Barriers and barrier management is not necessarily complex – as long as you’re faithful to your definitions, their operationalization and conceptual model.
- So what’s new? You’ll need a modelling tool which ties it all together.
- In order to understand how barriers perform it is necessary to;
  - identify the functions of the system, on both system and element levels (incl. tasks!!)
  - know what functions different systems and elements performs in various scenarios
  - understand the interaction and interfaces between the different systems and elements
- Keep in mind the **tasks** performed by operator(s) and associated PSFs.
- The building bricks are already available – just make sure to bring a proper drawing
  - Requirements can be found in recognized standards
  - For risk reduction beyond what is provided by standards, traditional safety-, HF studies and risk assessment techniques will suffice.
- Draw upon established safety and risk management frameworks
  - Various standards for safety & risk management can be adapted, e.g. ISO31000.
References and recommended reading

- Rosness et al. (2002). Feiltoleranse, barrierer og sårbarhet. STF38 A03404
Questions?
Contact details

Sondre Øie

Senior Consultant

*Operational Safety*

Risk Management Solutions

DNV Maritime and Oil & Gas

Mobile: +47 948 61 628

[www.dnv.com](http://www.dnv.com)
Safeguarding life, property and the environment