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Cerebral Instinct

Evaluation, Visualization and Monitoring of Cumulative Risk Exposure Resulting from Safety Critical Hardware and Human Barriers Deviation

Current industry position on Cumulative Risk Management

01

Limited consideration and visibility of cumulative risk associated with barrier deviations

02

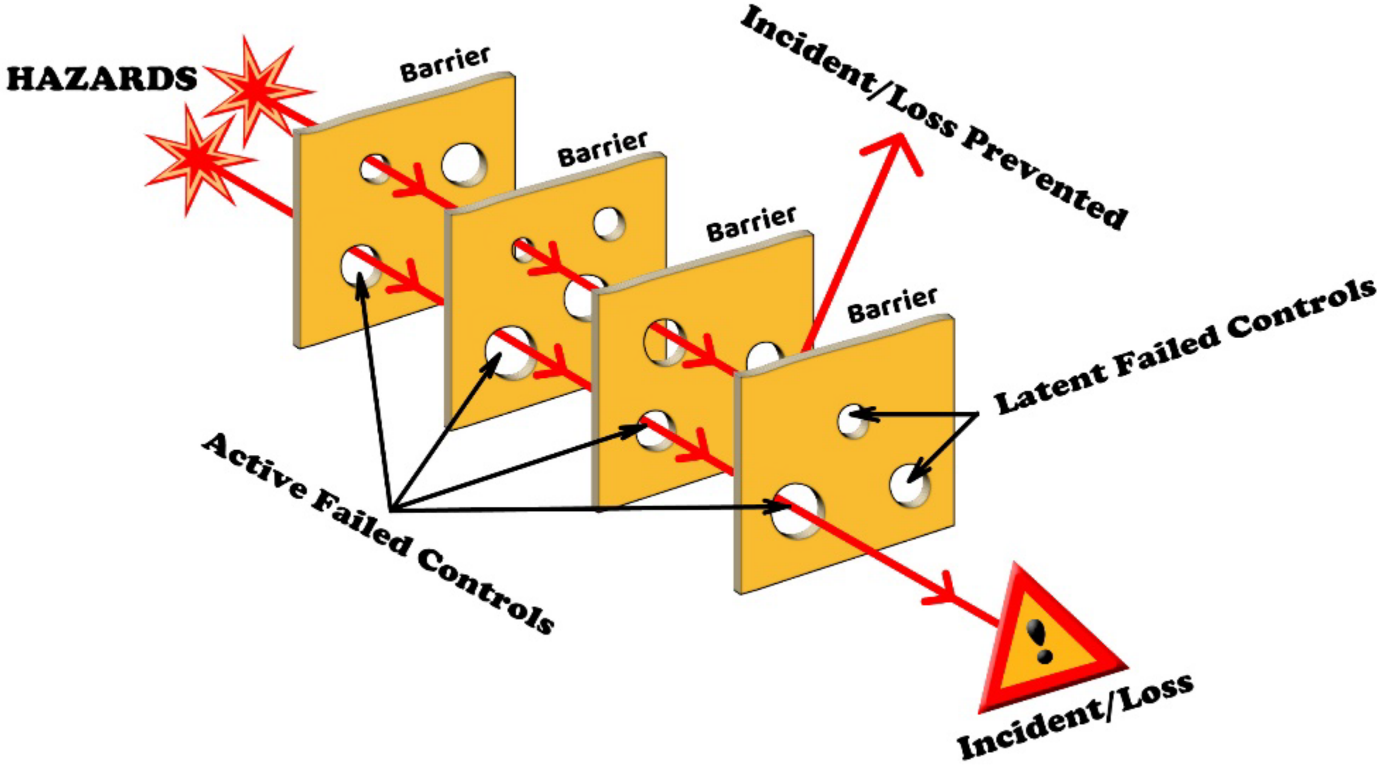
ORA and other allied methods for managing SCBs impairments or deviations are not adequate for cumulative risk management

03

Industry is overdue for a reliable and robust cumulative risk tool

Previous Accident and Cumulative Risk Contribution

Barrier Management Concept Illustration



The deficiencies or holes at each layer of protection are constantly increasing or decreasing based on management decisions and operational deviations

Previous Accident and Cumulative Risk Contribution - Examples

- Multiple layers of protection failed at the same time
- Lack of independent safeguards

(CAPECO) Tank Terminal Explosion

- Barrier failures that included procedural breaches
- Poor communication at shift handover
- Equipment malfunction was found

Texas City Refinery Explosion and Fire

- Investigation highlighted a series of failings relating to equipment and management system failures

Piper Alpha

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Photos from CSB

Barrier Deviation Management Methodologies

Operational Risk Management

Current range of programs to manage impaired SCBs and other defects include:

- ORA or similar process such as Safety Critical Risk Assessment (SCRA)
- Safety Critical Element Impairment Risk Assessment (SCEIRA)
- Safety Critical Element Failure (SCEF) and Deviation Control Risk Assessment (DCRA)

Whilst these SCB deviation management programs can be effective, they are often heavily weighted towards monitoring the integrity of hardware systems or SECEs and, as highlighted by the UK HSE, are limited in providing indication of the overall exposure caused by multiple barrier defects

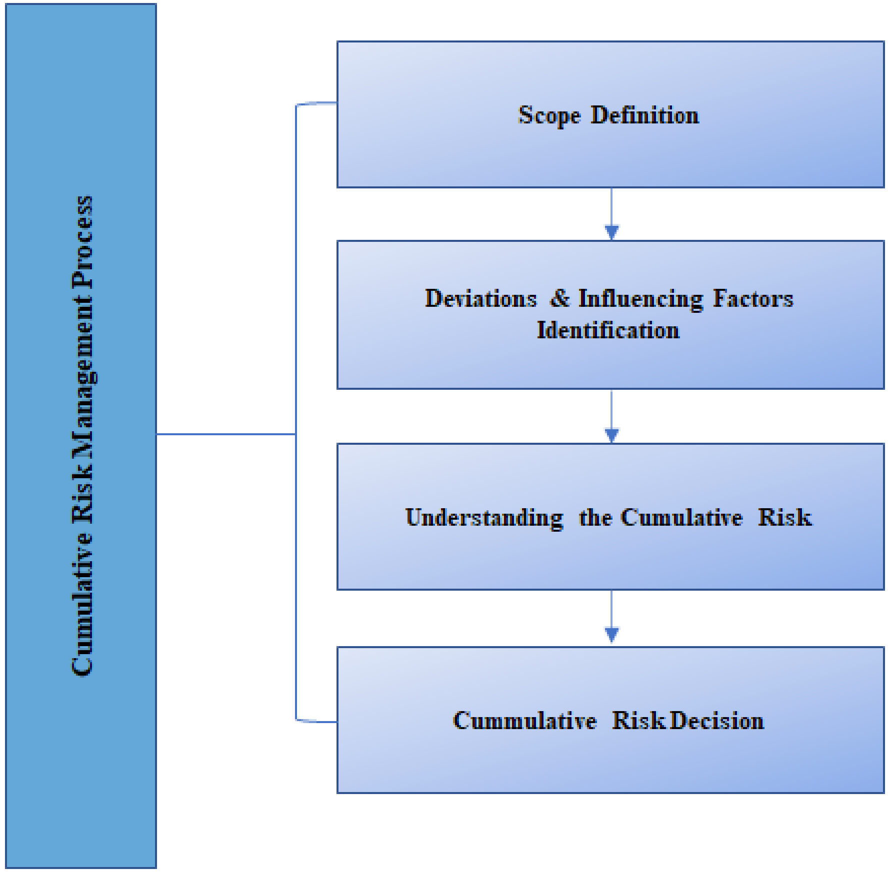
Cumulative Risk Model

Blacklaw (2013) describes a cumulative risk assessment barrier model used within BG Group's upstream asset:

- The methodology is based on the Swiss Cheese model concept
- The tool draws data from Permit to Work and Computerised Maintenance Management System (CMMS) and combine the data to provide a traffic lighted risk profile for each installation

It is inherently limited as it focuses primarily on hardware systems and is based on a simplified barrier concept which does not consider all foreseeable accident paths or scenarios that could lead to a major accident and the interdependencies of associated SCBs

Cumulative Risk Guideline

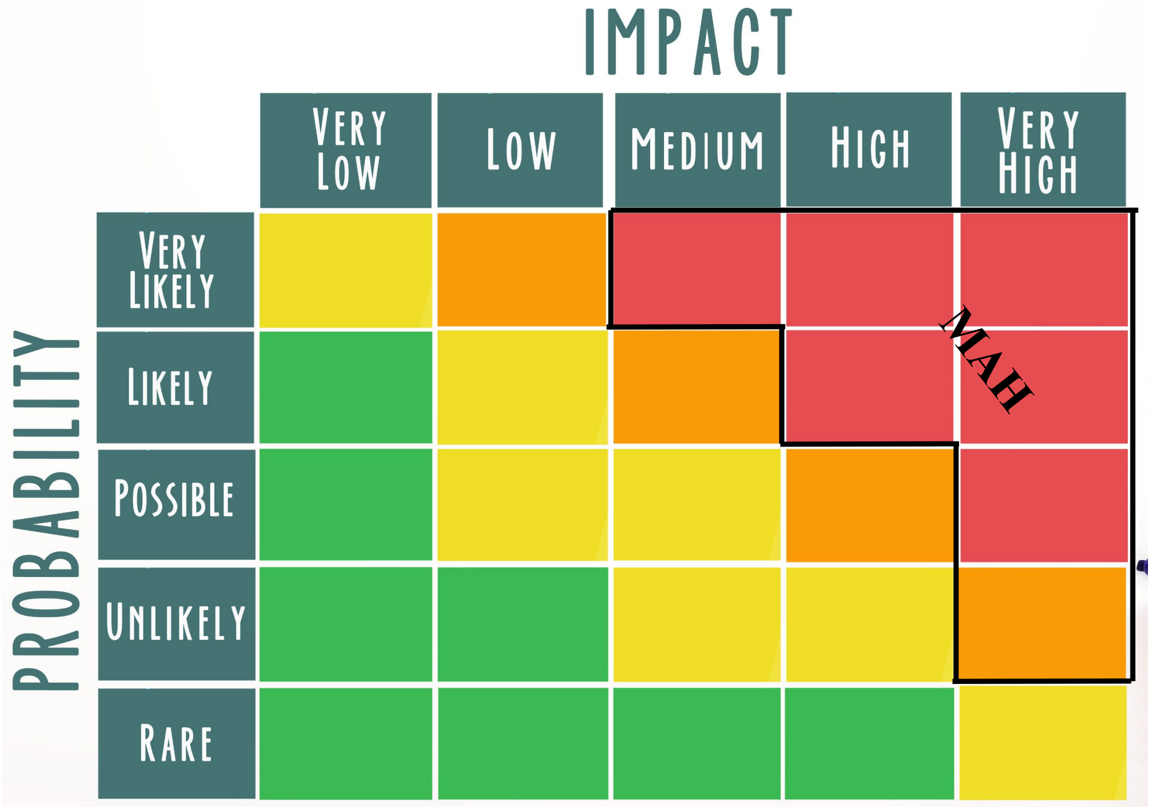


- Scope definition requires that all deviations and influencing factors that might affect the system being considered are included in the assessment.
- Once this is agreed, deviations are identified which can be hardware, human or process.
- Step 3 may require filtering where there are large number of deviations. The filtered deviations are then grouped, interactions between them identified, and associated cumulative risk assessed
- Step 4 involves a collective decision to establish if the cumulative risk has been adequately addressed and the remedial measures to be implemented.

The Guideline advises that whatever method is chosen to assess cumulative risk there must be sufficient certainty in its outcome. At the very least, the process should enable a veritable and pragmatic basis for making informed decision on cumulative risk acceptability.

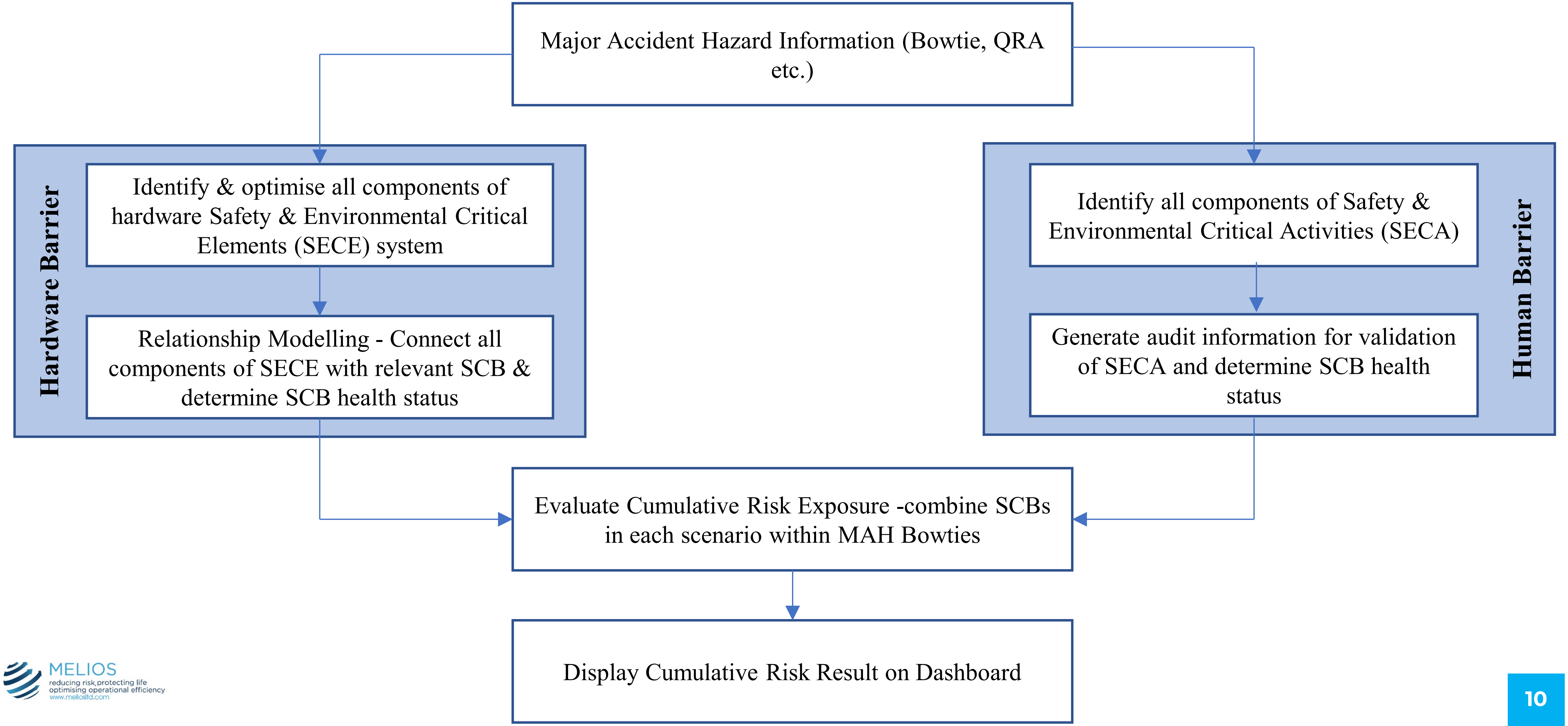
Proposed Methodology for Cumulative Risk Management

Risk Assessment Matrix (RAM)



- The starting point of a risk management process is the identification of hazards.
- The risk associated with the hazards are then assessed and ranked using a RAM.
- In the oil and gas industry, hazards carried forward for detailed analysis are typically known as Major Accident Hazards (MAHs).

Proposed Methodology for Cumulative Risk Management



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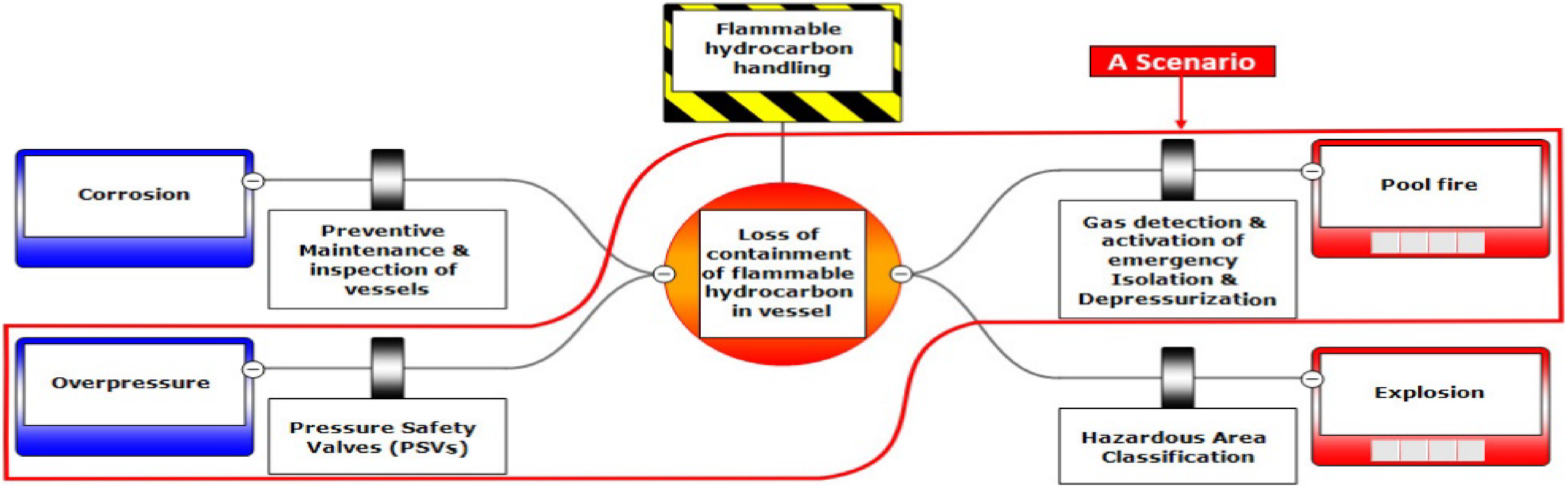
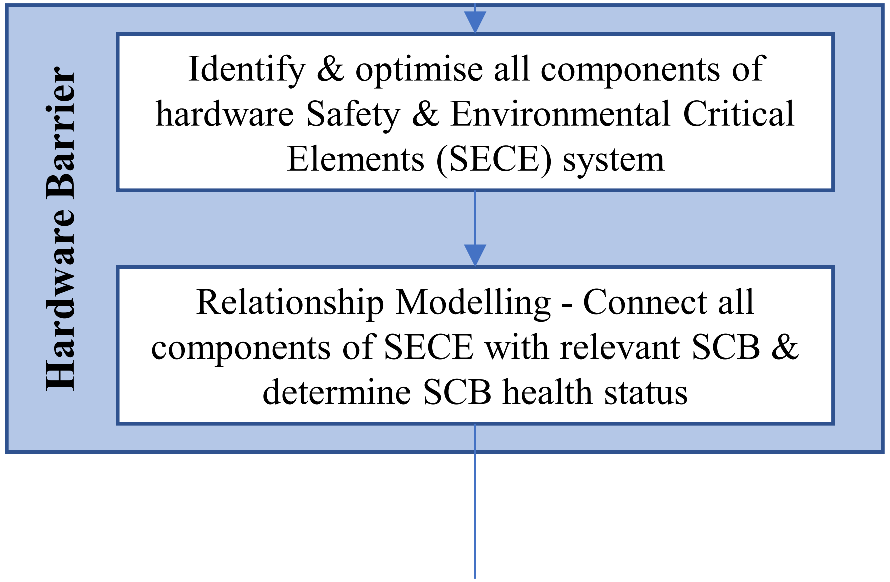
Major Accident Hazard Information

Identify all MAH scenarios - Bowtie and QRA are well suited for this purpose.



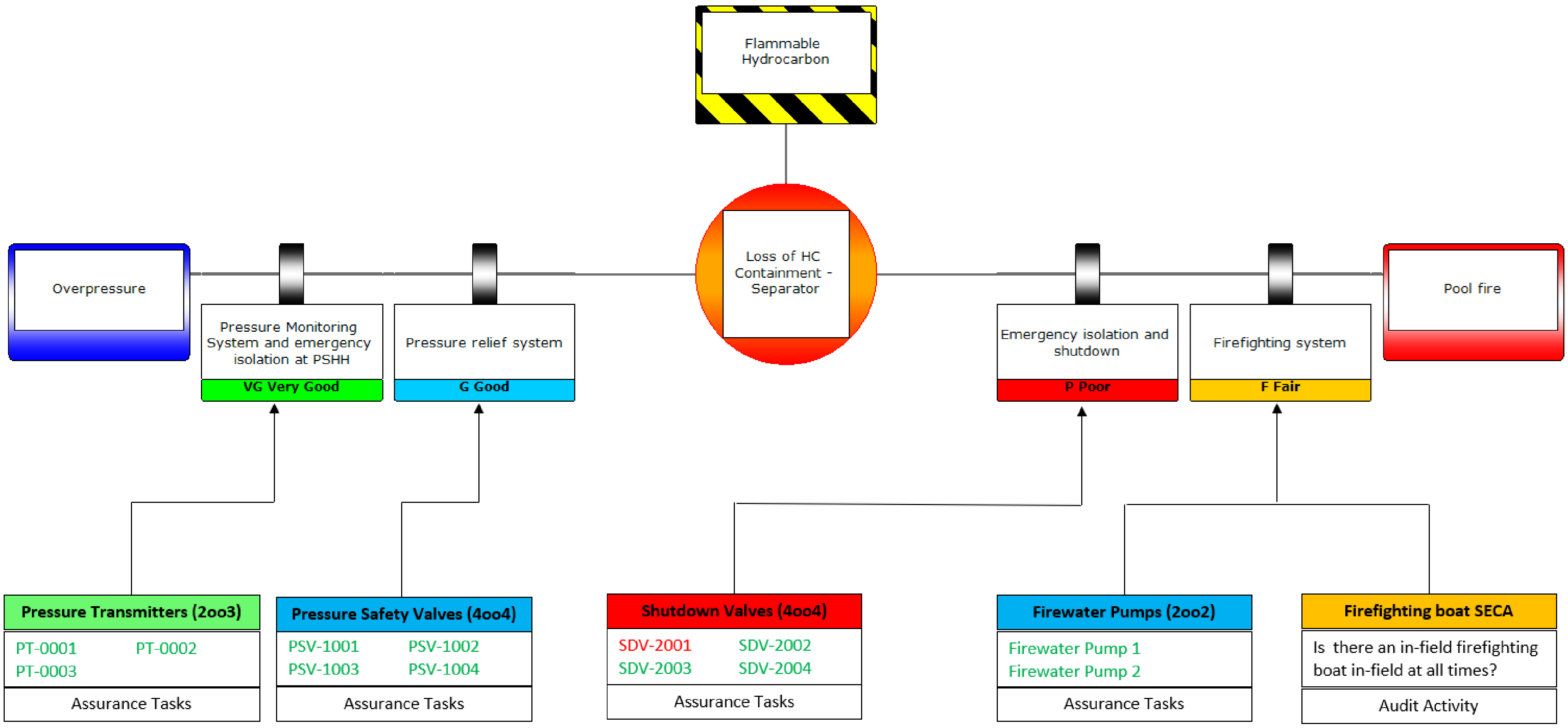
Hardware SCB Components and Optimisation



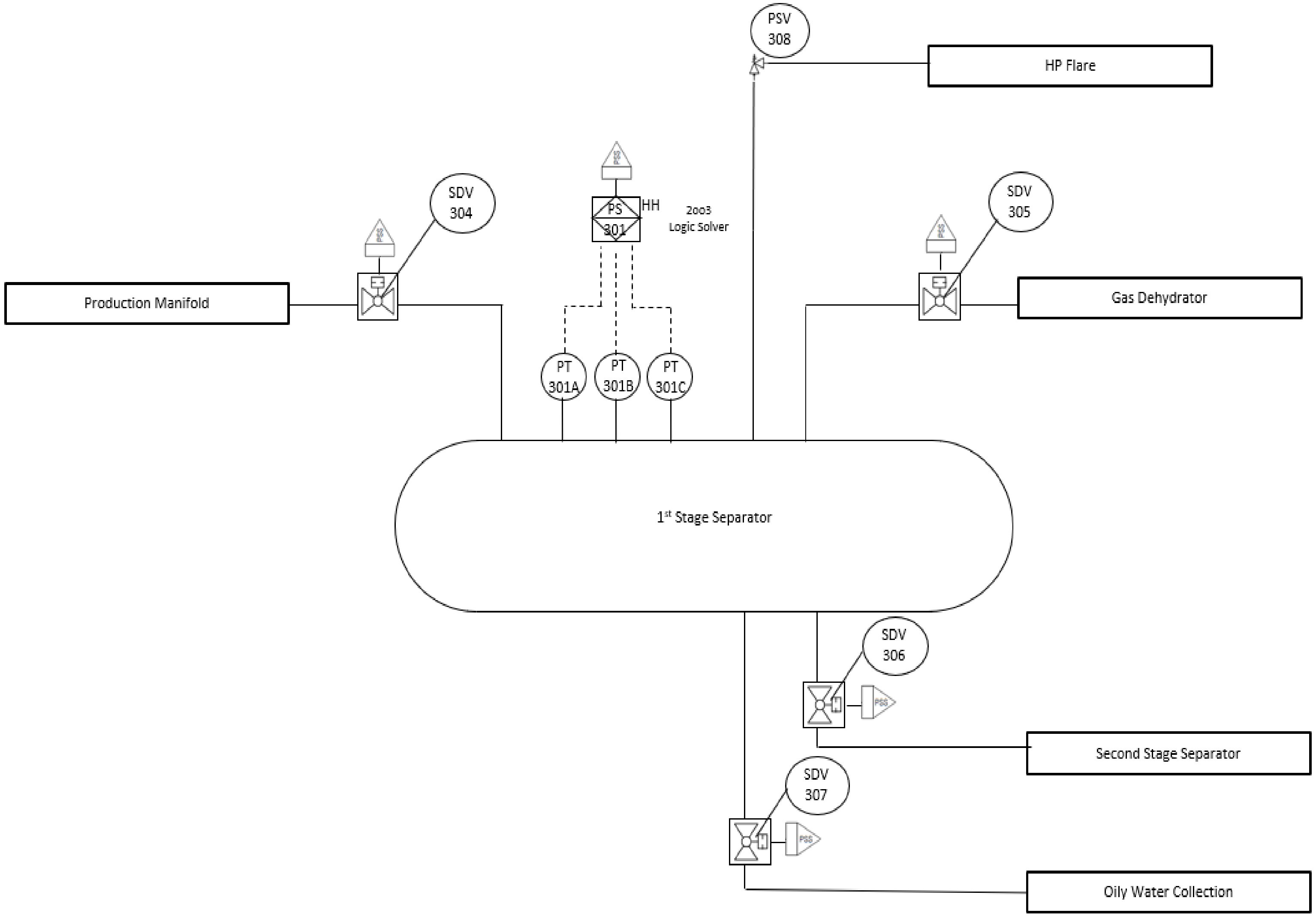
- Establish safety criticality of FLOCS and their assurance routines
- Establish if safety critical function is relevant to overall SECE performance.
- Obtain optimised list of SECEs.

Hardware barriers are made up of SECEs, their sub-systems, components or Functional Locations (FLOCs) and assurance routines

Barrier Composition



Relationship Modelling - Pressure Trip Example



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Pressure Trip Example

Pressure monitoring system relationship modelling and key

Barrier	System	SubSystem	Part
Pressure Monitoring System and emergency isolation at PSHH	Pressure monitoring system (3x50%)	Pressure Transmitter A 1x100%	PT 301A
		Pressure Transmitter B 1x100%	PT 301B
		Pressure Transmitter C 1x100%	PT 301C

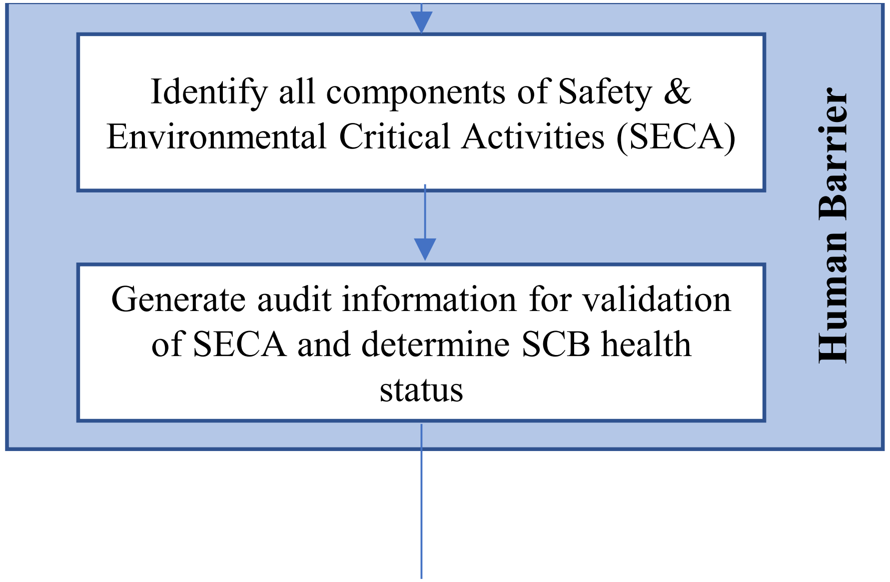
Voting Logic is represented as AxY%. where:
A = Number of Subsystems/Parts Available
Y = The Percentage coverage contribution each Subsystem/Part provides
If A x Y > 100%, The System provides Full Protection + Redundancy = Very Good
If A x Y = 100%, The System provides Full Protection = Good
If A x Y < 100%, The system provides Partial or no Protection = Fair / Poor

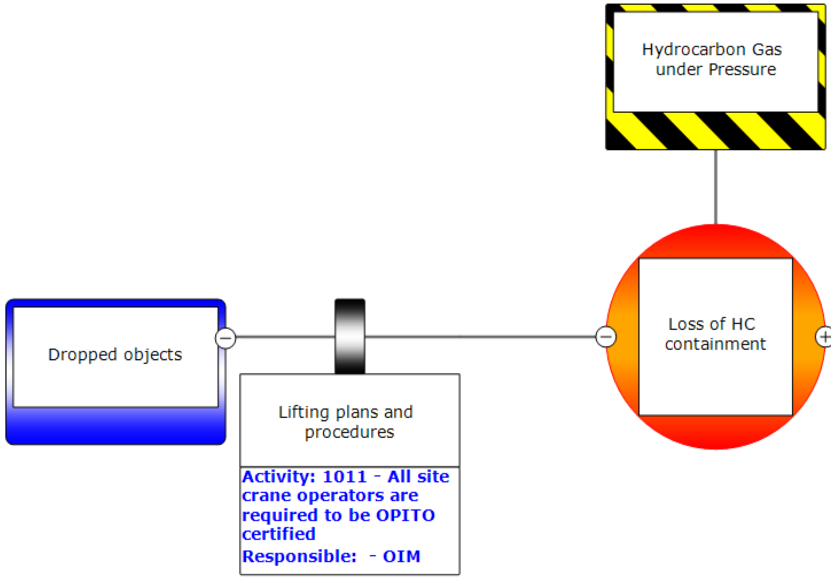
Part Key
Offline
Online

Barrier/System/Subsystem Key

Very Good	Fair
Good	Poor

Safety and Environmental Critical Activity (SECA) Identification





Safety critical tasks from the management system are extracted, reviewed, and linked to the relevant barriers.

SECA Audit and Assurance

Following the SECA audit, all responses received are reviewed and assigned a numerical rating between 1 and 0 corresponding to Very Good, Good, Fair, or Poor depending on the response. The ratings are defined as follows:

- **Very Good** - full compliance.
- **Good** - Non-compliance which is deemed to have only a minor impact on the level of protection offered by the applicable SCB.
- **Fair or Poor** rating of SECA is assigned depending on the level of impact a non-compliance has or potentially has on the protection offered by an SCB.

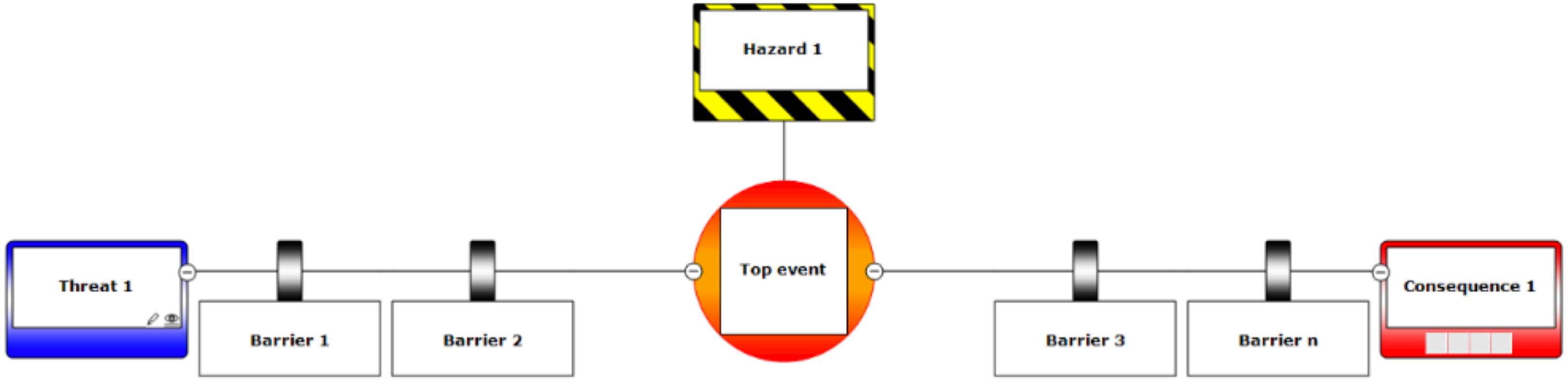
Survey Question: are all crane operators OPITO Certified?

The possible answers and ratings would be:

- All crane operators are OPITO certified – **Very Good**
- Some crane operators are not OPITO certified but have certifications from other recognized bodies and are supervised by personnel with OPITO certification – **Good**
- Some crane operators are not OPITO certified – **Poor**

Cumulative Risk Exposure Evaluation

Scenario Exposure Evaluation



Scenario Exposure Evaluation

$$\text{Scenario Exposure} = \text{Reliability} \times \text{Adequacy}$$

$$\text{Scenario Exposure} = (R_{B1} \times A_{B1}) + (R_{B2} \times A_{B2}) + (R_{B3} \times A_{B3}) + \cdots (R_{Bn} \times A_{Bn})$$

$$\text{Scenario Exposure} = \sum_{i=1}^{n} (R_{Bi} \times A_{Bi}) \text{ --------------- (1)}$$

Where:

R_{Bi} = Reliability of barrier i,

A_{Bi} = Adequacy of barrier i.

SCB reliability is a measure of the health status of a barrier. It is an indication of how often a barrier will perform, on demand, relative to its performance criteria.

SCB Adequacy is related to the barrier type in the conventional hazard management hierarchy and the safety critical function it is required to perform to protect against the development of an unwanted event.

Cumulative Risk Tolerability Evaluation

$$P_d = P_i - P_a \text{ - - - - - - - - - - - - } (2)$$

Where:

P_a = Summation of the actual protection all the SCBs offers against a Scenario

P_i = Summation of the ideal protection all the SCBs offers against a scenario i.e., all barriers operating as intended expressed as

$$P_i = \sum_{i=1}^{n} (R_{Bi} \times A_{Bi})_{ideal} \text{ - - - - - - - - - - - - - - } (3)$$

P_a = Actual protection against a scenario expressed as

$$P_a = \sum_{i=1}^{n} (R_{Bi} \times A_{Bi})_{actual} \text{ - - - - - - - - - } (4)$$

A percentage ratio of the difference in protection (P_d) and the ideal protection (P_i) is then computed to determine the risk tolerability, i.e.,

$$Risk\ Tolerability\ (R_T) = \frac{P_d}{P_i} \times 100\% = \frac{P_i - P_a}{P_i} \times 100\% \text{ - - - - - - - - } (5)$$

Where RT ≥ 40%, restoration of the failing SCB or at the very least implementation of appropriate mitigation is advised. Selection of the 40% or greater risk tolerability threshold is predicated on loss of the preventive SCBs.

When the RT for all scenarios in a Bowtie are computed the highest percentage value is used as representative level of exposure to that MAH. The representative RT thus indicates the cumulative risk exposure as it takes account of all barrier deviations, barrier types and temporary mitigations related to the MAH.

Validation of Methodology

Operational Experience

Operational Deployment
Methodology developed into a digitized application which has been deployed across several major operating assets. The application which has been running for several years on some of these assets includes provision for automatic and manual data pick up from CMMS, action tracking registers, override/ inhibit register, deviation register etc. The tool also has a dashboard which displays cumulative exposure across multiple assets and drivers or influencing factors can be identified up to assurance routine or SECA tasks level

Feed back from Operational Experience
Application enables, for the first time, a good understanding of the cumulative impact of SCB deviations, making visible link to MAH exposure, and enhancing risk-based decision making. Gaps in the maintenance management system which were hitherto unknown have been brought into focus helping the organisation identify where improvements are needed. The tool has been very useful in drawing the attention of asset and management personnel to barrier impairments that poses real risk exposure but have lost visibility and become latent due to operational exigencies Encourage frank conversations between management and asset personnel on barrier deviations backlog and prioritisation Provides a basis for Specific, Measurable, Achievable, Relevant and Timebound (SMART) Key Performance Indicators (KPIs) that drive real safety benefit

Retrospective evaluation of previous notable incidents in the oil and gas industry

FPSO Cidade de São Mateus Gas Explosion

Accident was caused by a loss of condensate containment in the pump room which resulted in 9 fatalities and injuries to 26 workers.

CAPECO Tank Terminal Explosion

Terminal Tank fire caused by tank overfilling. It resulted in damage to 17 out of the 48 storage tanks, and environmental damage.

Tesoro Anarcortes Oil Refinery Explosion

Ignited release due to HTHA in the heat exchanger of the NHT unit. Resulting explosion and fireball caused 7 fatalities and significant asset damage.

Photo source: US Chemical Safety Board

Retrospective evaluation of previous notable incidents in the oil and gas industry

1. Bowtie Creation

Review investigation report and retrospectively create MAH Bowtie diagram

2. MAH Bowtie Information

Deduce threats, consequences, top events, and barriers from the investigation reports

3. Reliability & Adequacy of Barriers

Reliability and adequacy ratings for each barrier assigned and adjusted in turn to reflect their functional status as indicated in the investigation reports.

4. Cumulative Risk Exposure

Risk Tolerability (RT) determined and displayed on a dashboard in the software

Retrospective evaluation of previous notable incidents in the oil and gas industry

Cumulative Risk Exposure - FPSO Pump Room Explosion

Scenarios

Scenarios	Scenarios Status	% Deterioration	Barriers	Very Good	Good	Fair	Poor
T-CDSM.02-C-CDSM.01		69%	8	1	1	0	6
T-CDSM.04-C-CDSM.01		68%	6	1	1	0	4
T-CDSM.02-C-CDSM.02		66%	9	0	3	0	6
T-CDSM.04-C-CDSM.02		64%	7	0	3	0	4
T-CDSM.03-C-CDSM.01		60%	5	1	1	0	3
T-CDSM.03-C-CDSM.02		54%	6	0	3	0	3
T-CDSM.01-C-CDSM.01		42%	6	1	2	0	3
T-CDSM.01-C-CDSM.02		41%	7	0	4	0	3

Showing **8** of **8** entries. Previous Next

Cumulative Risk Exposure – CAPECO Incident

Scenarios

Scenarios	Scenarios Status	% Deterioration	Barriers	Very Good	Good	Fair	Poor
P-CPC.01.01-C-CPC.03		67%	4	0	1	0	3
P-CPC.01.01-C-CPC.02		65%	7	0	1	1	5
P-CPC.01.01-C-CPC.01		64%	6	0	1	1	4

Showing **3** of **3** entries. Previous Next

Cumulative Risk Exposure – Tesoro Anacortes Refinery Accident

Scenarios

Scenarios	Scenarios Status	% Deterioration	Barriers	Very Good	Good	Fair	Poor
T-TES.02-C-TES.01		56%	4	0	0	2	2
T-TES.01-C-TES.01		39%	5	1	0	1	3

Showing **2** of **2** entries. Previous Next

These results show that the failing barriers would have been flagged and early warning of vulnerability to the major accident provided to frontline and management personnel if the application was deployed on these facilities.

Conclusion

- A methodology for cumulative risk assessment has been developed that enables evaluation, visibility and monitoring of cumulative risk exposures created by human and hardware barrier deviations, and accounts for interactions and interdependencies across SCBs.
- The underpinning concept behind the methodology is consistent with established risk management techniques and with the OGUK Guideline on Cumulative Risk.
- This approach provides robust and verifiable means of assessing cumulative risk exposure with limited manual intervention.
- It enables dynamic barrier management, while helping organisations to focus attention on main drivers of cumulative risk exposures.
- It helps to deepen understanding of major accident cumulative risk and has been shown to provide tangible and pragmatic risk reduction benefit for operator of major hazard installations.

Future Development

Whilst the methodology in its current form shows very promising results there is opportunity for further refinement of the algorithm to enable inclusion of more variables such as threat frequency, threat category and ‘smart automation’ which will reduce human error in data processing and facilitate Predictive Analytics.

Contact

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