Cumulative Risk Assessment Model
to Analyze Increased Risk due to Impaired Barriers in Offshore Drilling Rigs

Syeda Zohra Halim
A Holistic Look into Risk

- It is all technical factors!!
- Wrong! It's about operational factors
- No! No! It's organizational factors!
- No! It is human factors!

https://wildequus.org/2014/05/07/sufi-story-blind-men-elephant/
Deviations can interact and sum up

Figure: Cumulative risk and tolerability [1]
Past Incidents [3,4]

Macondo Disaster
April, 2010
11 killed
4.9 million barrels of oil spilled
Fine: $18.7 billion + others


Texas City Refinery Explosion
March, 2005
15 killed, 180+ injured
Fine: $87 million

Cumulative Risk Assessment: The Challenge

- Integration of human and organizational factors with technical and operational factors
- Complexity and size of system
- Dependencies of components and events
- Temporal aspects (Dynamic)
- Uncertainties of parameter estimation
Objective

- Develop a framework for merging all factors together and build a model based on this framework that will enable determination of cumulative risk

- Identify causes behind offshore incidents and understand the effect of impaired barriers

- Conduct literature review for developing required framework

- Find applicable tool for developing a model that can handle required criteria
# Previous Work

<table>
<thead>
<tr>
<th>Accident Evolution and Barrier Analysis (AEB): Svensson (2001)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrier Analysis (BA): Dianous and Fievez (2006)</td>
</tr>
<tr>
<td>Management Oversight and Risk Tree (MORT): Johnson (1980)</td>
</tr>
<tr>
<td>Events and Causal Factor Charting and Analysis (ECFCA): DOE (1999)</td>
</tr>
<tr>
<td>Swiss Cheese Model: James Reason (1990, 1997)</td>
</tr>
<tr>
<td>PyraMAP: Bellamy et. Al (2008)</td>
</tr>
<tr>
<td>Barrier and Operational Risk Analysis (BORA): Aven et.al (2006)</td>
</tr>
<tr>
<td>Bowtie: ICI (1979)</td>
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<tr>
<td>Tripod BetaGroeneweg (2008)</td>
</tr>
</tbody>
</table>

… and many more
## Previous Work (2)

<table>
<thead>
<tr>
<th>APPROACH</th>
<th>ALL FACTORS</th>
<th>QUANTITATIVE</th>
<th>DEPENDENCY</th>
<th>DYNAMIC</th>
<th>OTHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swiss Cheese Model: James Reason</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>FT becomes too large</td>
</tr>
<tr>
<td>MORT: Johnson</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>STAMP/ STPA: Nancy Leveson</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>No software to identify all the loops, depends on expertise and control structure diagram</td>
</tr>
<tr>
<td>FRAM: Erik Hollnagel</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td>Requires iteration, difficult and time consuming</td>
</tr>
<tr>
<td>BORA, Risk-OMT: Aven et. al.</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>Scoring depends on RIFs and hence on the expert team</td>
</tr>
</tbody>
</table>
Objective

• Develop a framework for merging all factors together and build a model based on this framework that will enable determination of cumulative risk

Identify causes behind offshore incidents and understand the effect of impaired barriers

Conduct literature review for developing required framework

Find applicable tool for developing a model that can handle required criteria
Available Tools

- Event-Cause Trees (Includes Fault Tree, Event Tree, Bow-Tie)
- Markov Chains
- Bayesian Network
- Petri Nets
Bayesian Networks

- It is a directed graph consisting of a set of nodes and arcs.
- Handles dynamic systems, distributions and dependencies and allows probability updating.
- Based on Bayes Theorem:

\[
P(p_i \mid \) = \frac{P(\mid p_i)P(p_i)}{\sum_{i=1}^{k} P(\mid p_i)P(p_i)}
\]
Petri Net Basics

- Petri Nets is a directed bipartite graph where system is analyzed by movement of tokens from one place to another via firing of transitions.
## Case Study

<table>
<thead>
<tr>
<th>V1</th>
<th>C1</th>
<th>C2</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>Open</td>
<td>Open</td>
<td>Delayed Rupture</td>
</tr>
<tr>
<td></td>
<td>Close</td>
<td></td>
<td>Success</td>
</tr>
<tr>
<td>Close</td>
<td>Open</td>
<td>Open</td>
<td>Early Rupture</td>
</tr>
<tr>
<td></td>
<td>Close</td>
<td></td>
<td>Delayed Rupture</td>
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<tr>
<td>Open</td>
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<tr>
<td>Close</td>
<td>Open</td>
<td>Close</td>
<td>Early Rupture</td>
</tr>
<tr>
<td></td>
<td>Close</td>
<td></td>
<td>Rupture</td>
</tr>
</tbody>
</table>
Case Study: Event Tree

```
Initiating Event
  V1 Close 0.9
    C1 Open 0.9
      C2 Open 0.59
        Delayed Rupture
      C2 Close 0.41
        Success
    C1 Close 0.1
      C2 Open 0.59
        Early Rupture
      C2 Close 0.41
        Rupture
  V1 Open 0.1
    C1 Open 0.9
      C2 Open 0.59
        Delayed Rupture
      C2 Close 0.41
        Success
    C1 Close 0.1
      C2 Open 0.59
        Early Rupture
      C2 Close 0.41
        Delayed Rupture
```
Case Study: Bayesian Network

- Bobbio et al. (2003)
- Bearfield et al. (2005)
- Weber et al. (2012)
- Khakzad et al. (2013)
Case Study: Petri Nets

Liu et al. (1997)
Labeau et al. (2000)
Nyvlt et al. (2012)
Pasman (2015)
# Results

<table>
<thead>
<tr>
<th></th>
<th>ET</th>
<th>BN</th>
<th>PN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful Mitigation</td>
<td>36.90%</td>
<td>36.90%</td>
<td>36.89%</td>
</tr>
<tr>
<td>Early Rupture</td>
<td>5.90%</td>
<td>5.90%</td>
<td>5.89%</td>
</tr>
<tr>
<td>Rupture</td>
<td>3.69%</td>
<td>3.69%</td>
<td>3.67%</td>
</tr>
<tr>
<td>Delayed Rupture</td>
<td>53.51%</td>
<td>53.51%</td>
<td>53.55%</td>
</tr>
</tbody>
</table>
Conclusion

• An integrated model may be required to analyze cumulative risk
• A framework is to be used to merge technical, operational, human and organizational factors together
• BN and PN achieve their common goal through different approaches. Selection should depend on intended application
• Further work on development of the model is underway
Acknowledgements

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• All members of MKOPSC
References


References (Contd.)


If history repeats itself, and the unexpected always happens, how incapable must Man be of learning from experience.

—George Bernard Shaw
A Simple Petri Net Example

Reachability Graph:

P1: Operating (ON)
P2: Failed (OFF)
A New Approach

• Use of two colored tokens to represent probability of failure and success
• Straight forward and easy approach to obtain system’s failure probabilities
• Reduced simulation time compared to previous approaches