Enabling Safer Offshore Energy Operations: Current Advances in Safety and Risk Assessment

Hosted by:
Health Safety & Environment
SPE Gulf Coast Section

September 10th , 2019

MarathonOil
TEES MARY KAY O'CONNOR PROCESS SAFETY CENTER
OESI

Enabling Safer Offshore Energy Operations

Ocean Energy Safety Institute

10 September 2019

Jim Pettigrew, CAPT, USN(Ret)

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In memoriam

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DoI Intent…

"The *funding for this initiative* was provided to establish an institute that would operate ***independently*** of the Department of the Interior while also supporting and enhancing Departmental programs through ***collaborative research and development*** and training to help identify operational improvements in the areas of offshore drilling and production safety and spill prevention.

This is an effort to establish an institute that can ***work with academia, the oil and gas industry, regulators and non-governmental organizations*** on the extremely important issues of increasing ***worker safety and environmental protection*** during the exploration, development and production of the nation's valuable offshore oil and natural gas resources."

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Advisory Committee

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Dialogue, Research, Training

- Forums for Dialogue
  - Multiple event discussions have informed research areas and themes
  - 30 April 19 Leading Indicators Forum
- Research
  - Collaborative Research
    - Human Factors Engineering
    - Zonal Isolation
    - New Materials
  - Hilcorp Liberty Project
  - Leading Indicators Dashboard
- Training and Continuing Education opportunities
  - BSEE specific opportunities
    - CFD, Drilling Margin/Fracture Gradient, RTM, …
  - Hazard Analysis for LNG Facilities, Onshore and Offshore
  - New Materials for Offshore O&G: From Molecule to Design
  - Human Factors Engineering and Offshore Drilling: Designing for Safety
  - Other Process Safety related instruction

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Institute Status

- Initial contract through November 2018
- Opportunity for No-Cost extension
- No-Cost extension granted through April 2020
- Developing Consortium opportunity

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Other Efforts

- OESI Research Highlights, 2018-2019
  - oesi.tamu.edu/research/highlights

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OESI-related Student Research

- *Human Factors in the Selection of New Technology for the Oil and Gas Industries*
  - Jehova Arenas (TAMU)
- *Cumulative Risk Assessment Model to Analyze Increased Risk Due to Impaired Safety Critical Elements in Offshore Resources*
  - Zohra Halim (TAMU)
- *Self-learning control of automated drilling operations*
  - *Parham Pournazari (UT)*
- *Resilience Engineering Framework Incorporating Prediction, Survival and Recovery Analysis*
  - Prerna Jain (TAMU)
- *Determining Pressure Drop and the Minimum Fluidization Velocity across a Gravel Pack Completion to confirm its Integrity*
  - Ankit Bhowmick (UH)

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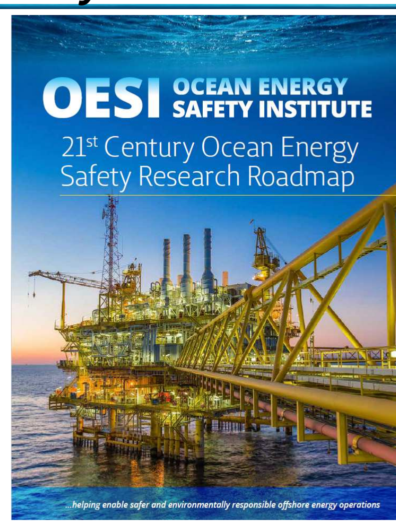
An informed way forward…

- Inform academic research with Industry Stakeholder priorities
- 21st Century Ocean Energy Safety Research Roadmap
  - oesi.tamu.edu/research/roadmap



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Leading Indicators Dashboard

- Leading Indicators in Well Control and Process Safety in Wells
  - April 30, 2019 in College Station, Texas
  - ~70 participants from 29 organization
- Leading Indicators Dashboard Next Steps
  - June 25 in Houston, Texas
  - ~18 participants from 12 organization
- Key points –
  - Clear consensus on importance of leading indicators-based tool and dashboard
  - Develop Statement of Requirements (SoR) addressing the appropriate customers
  - Develop user-specific customizable dashboard
  - Do not re-invent the wheel - fully leverage other efforts
  - Not another data-collection effort
- Way Forward meeting, October 16.

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LI Dashboard Project

- **Objective**
  - To engage industry in developing a dashboard where Leading Indicators (LIs) in well control could be –
    - tracked and displayed
    - provide early warning signs through a "traffic light system" of degradation or failures of well barriers
- Follow and implement a 4-step methodology for identifying failure mechanisms to developing LI dashboards
- Integrate process safety components and identify and define LI's based on – *operational performance, design, compliance, competency, risk management, reliability, audit, contractor management, management system and incident investigation*
- Project efforts carried out through a consortium arrangement

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Summary

- Background
- Forums for Dialogue
- Research
  - Leading Indicators Dashboard
  - Collaborative Research
- Continuing Education opportunities
- *All informed by Research Roadmap*

Thanks for your time…

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15

Cumulative Risk Assessment to Analyze Increased Risk due to Impaired Barriers in Offshore Facilities

Outline

- Introduction
- Current Approaches
- Framework and Methodology
  - Step 1: Extracting information from incidents
  - Step 2: Mathematical formulation
  - Step 3: Understanding relations between contributing factors
  - Step 4: Developing cumulative risk assessment model
- Conclusions

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1. Introduction

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The past

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

U.S. Chemical Safety and Hazard Investigation Board, "Investigation Report Executive Summary: Drilling Rig Explosion and Fire at the Macondo Well", Report No. 2010-10-I-OS, 2010

Piper Alpha Disaster
July, 1988
167 killed
Insured loss: $3.4 billion

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en.wikipedia.org/wiki/Piper_Alpha

19

1183
Fires and Explosions

41
Fatalities

2344
Injuries

Incidents keep on happening!

According to Bureau of Safety and Environmental Enforcement (BSEE), 2008- 2017

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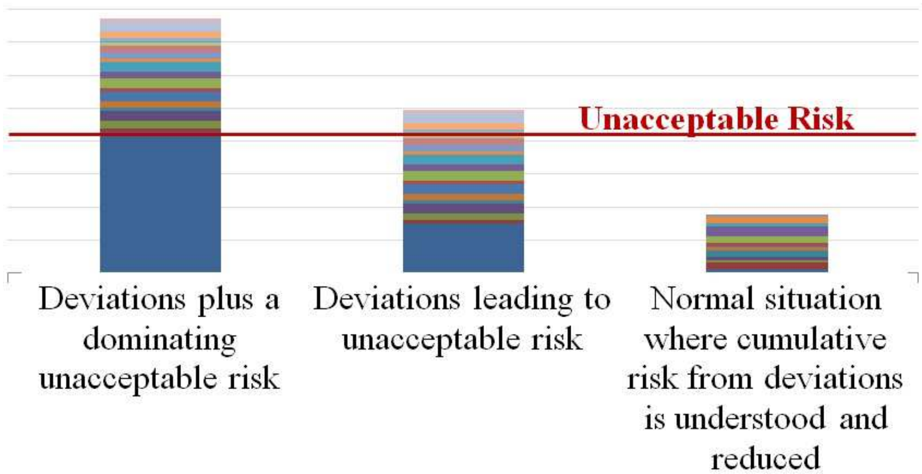
Deviations can interact and sum up



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Understanding hidden contributors behind risk

Technical Factors

Related to direct failure of equipment or operator

Non-Technical Factors

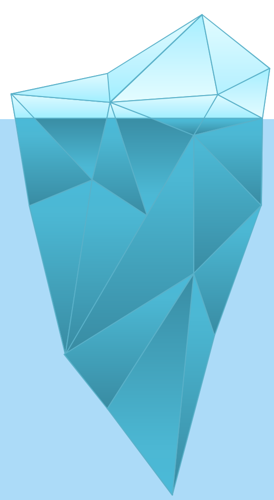
Related to organization and management

Multiple factors contributing to an incident

Highly dependent

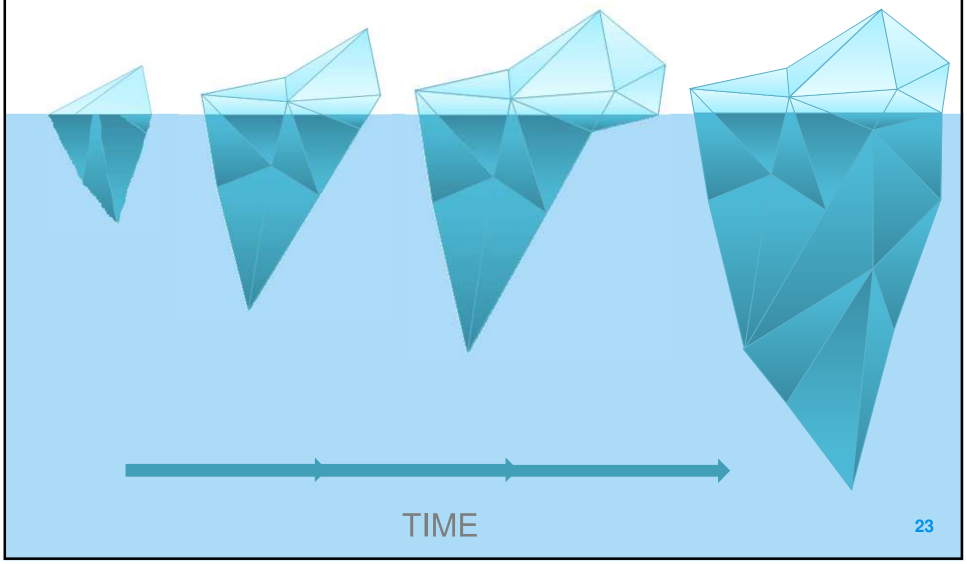
Changes with time

Large uncertainty



22

Understanding hidden contributors behind risk



23

Cumulative risk assessment

involves achieving an updated information about the dynamic risk through merging of technical, operational, human and organizational deviations existing within a facility using data that is specific to that facility and current in time

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Cumulative risk assessment: Challenges

Merging
of technical, operational, human and organizational factors

Dependencies
of factors and events

Dynamicity
of components affecting the system

.

Updating
to keep data plant-specific

Uncertainties
of parameter estimation

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2. Current Approaches

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Approaches for cumulative risk assessment

	Method	Provides quantitative risk estimate	Shows dynamic evolution of system	Considers dependency among factors	Addresses data uncertainty
Cause and Event Chain Approach	ET/FT	Yes	No	No	Yes
	HCL/ Risk_OMT	Yes	No	Partially	Yes
	I-Risk	Yes	No	Partially	Yes
Systems Approach	Accimap	No	Yes	Yes	N/A
	STAMP	No	Yes	Yes	N/A
	FRAM	No	Yes	Yes	N/A

Halim S. Z., Koirala, Y., Mannan, S. M., (2017), 'A Look into Cumulative Risk: Past, Present and Future', 2017 *AIChE Spring National Meeting: 13th Global Congress on Process Safety*, San Antonio.

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Tools for cumulative risk assessment

Fault Tree/ Event Tree/ Bowties	Markov Chain models
Bayesian Network -Hybrid Model	Petri Nets

Halim S. Z., Koirala, Y., Mannan, S. M., (2016), 'Probabilistic Methods of Quantitative Risk Analysis: A Case Study with Bayesian Network and Petri Net Approaches', *MKOPSC International Symposium 2016*, College Station.

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Data for cumulative risk assessment

Expert Opinion	Learning from Incident Precursor Data
• CCPS Guidelines for CPQRA • MANAGER • Papazoglou et al. • API RP 581 • TEC2O • BORA	• Meel et al. • SHIPP • DEMATEL-BN • SoTeRiA
LIMITATIONS: Tedious method. Not recommended for dynamic risk assessment	LIMITATIONS: Does not allow identification of the contributing factor that has the greatest influence on barrier failure probability Affect of HOF are not well handled

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Existing gaps

- Not many work focus on offshore facilities
- No method exists that tackles all the challenges of cumulative risk assessment
- For dynamic risk assessment, we have to move away from reliance on expert opinion
- Data used for risk assessment needs to be plant-specific
- Current methods using incident precursor data do not allow understanding of what is contributing the most to an increased risk

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3.

Framework and Methodology

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The Reflected Pyramid Concept

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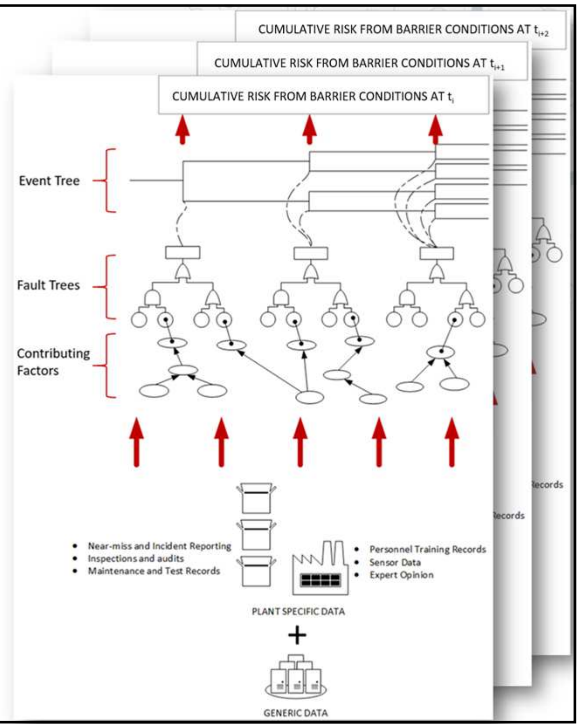
Framework



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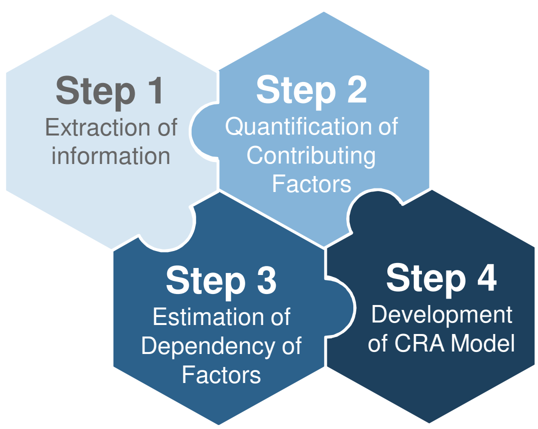
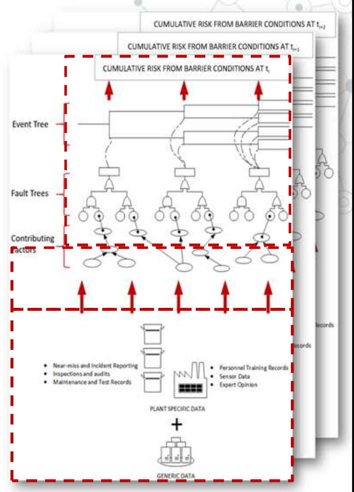
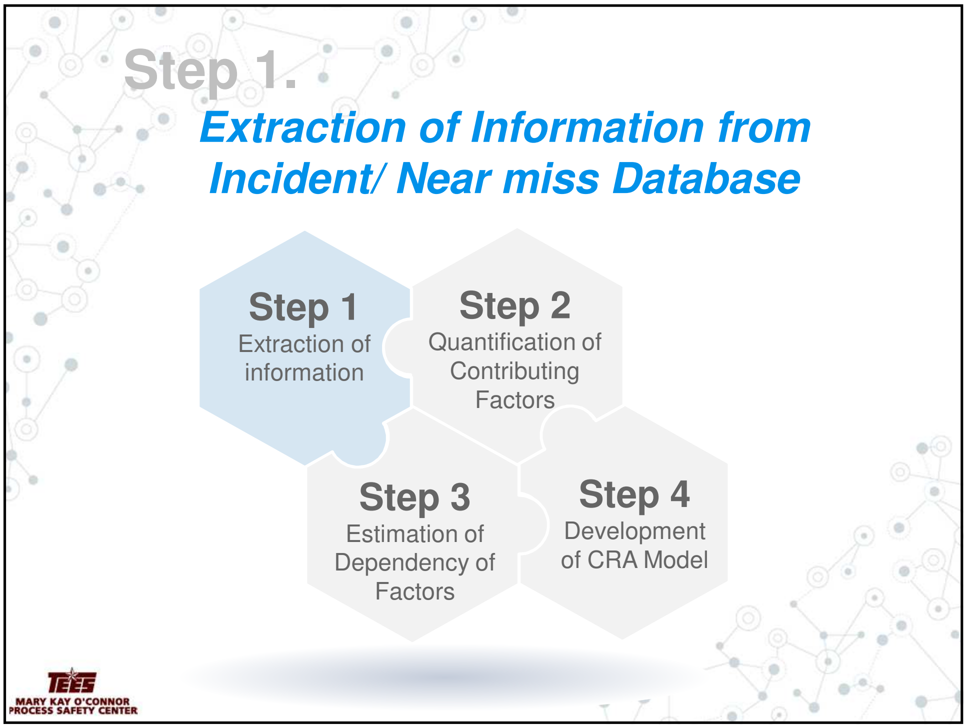
Step-by-step methodology





- Combination of information
- Case Study


Step 1.
Extraction of Information from Incident/ Near miss Database
Step 1
Extraction of information
Step 2
Quantification of Contributing Factors
Step 3
Estimation of Dependency of Factors
Step 4
Development of CRA Model
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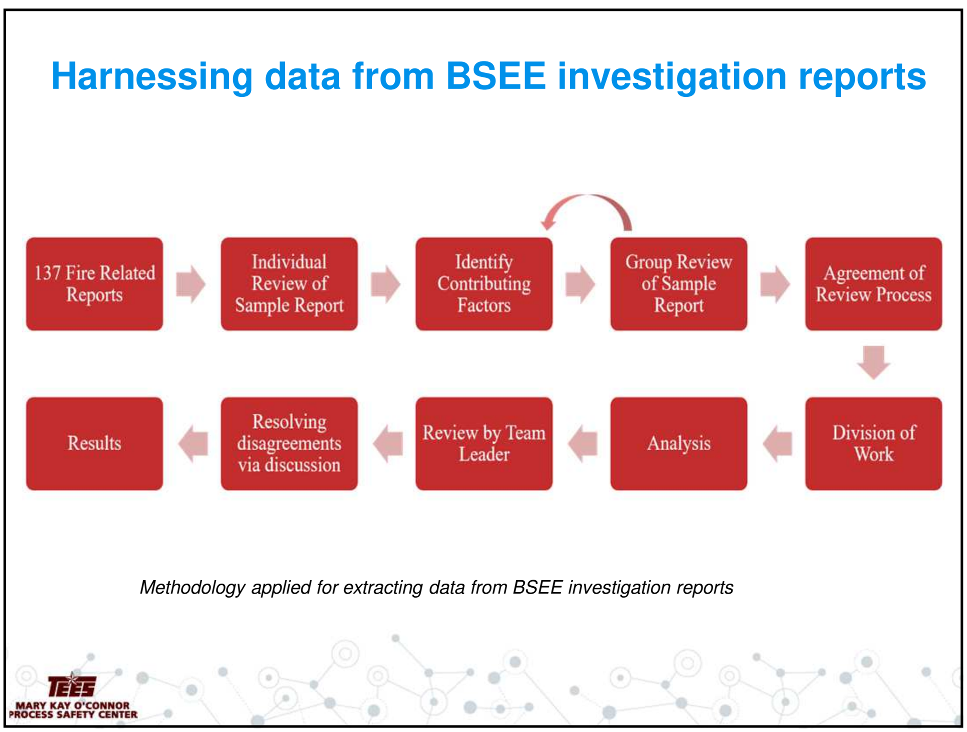
Harnessing data from BSEE investigation reports
137 Fire Related Reports
Individual Review of Sample Report
Identify Contributing Factors
Group Review of Sample Report
Agreement of Review Process
Division of Work
Analysis
Review by Team Leader
Resolving disagreements via discussion
Results
Methodology applied for extracting data from BSEE investigation reports
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Analysis of BSEE incident investigation reports

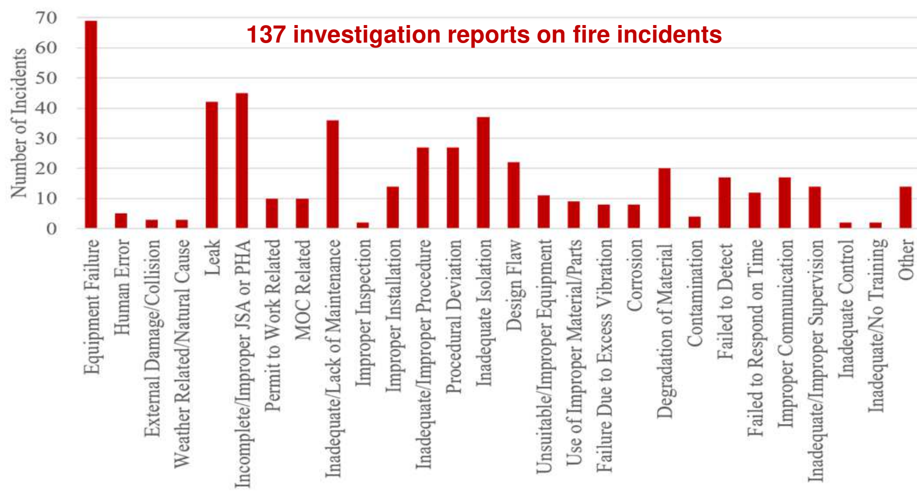
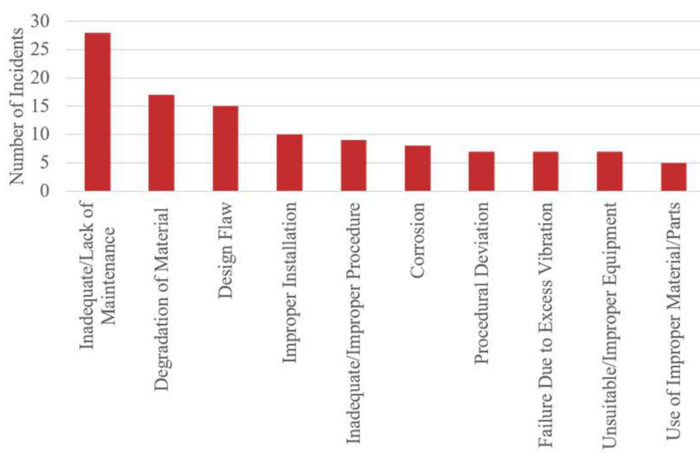
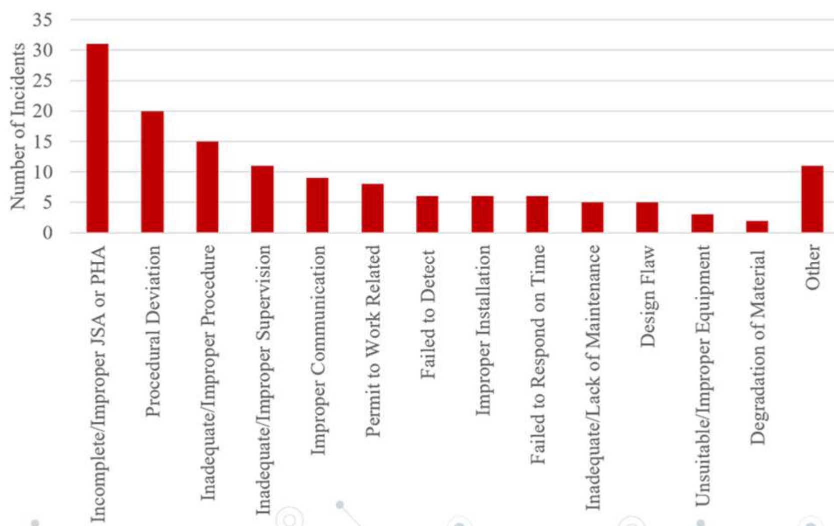


Figure showing factors that were identified in the analysis

Contributing factors with 'Equipment Failure'



Contributing factors with ‘Human Error’



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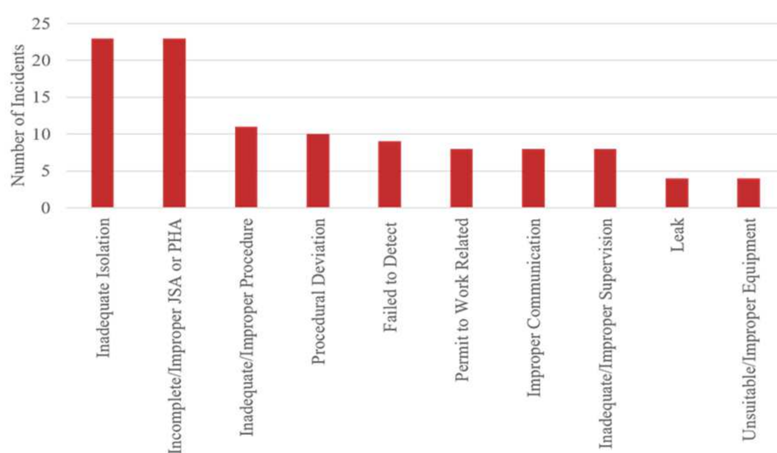
Contributing factors with ‘Hot Work’



Analysis also brought out what factors contributed to ‘Hot Work’ and ‘Leaks’ in offshore incidents

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Findings

- Methodology that provides a guide for extracting data of contributing factors from investigation reports
- Easy to identify equipment failure and human error as causes - deeper analysis revealed multiple contributing factors
- Statistical representation of contributors via counting
- Leading contributors: Inadequate or improper JSA (33%), isolation (27%), maintenance (26%) and procedure (20%) or procedural deviation (20%)
- Lesser contributors: Design flaw (16%), degradation of material (15%), failure to detect (12%), improper communication (12%), and inadequate supervision (10%) occurred less frequently

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Implementation challenges

- More detailed information = Better analysis
- Consideration of near misses
- Design of a robust incident reporting system
- Collection of data
- Other sources can also provide data (maintenance records, audits *etc.*)

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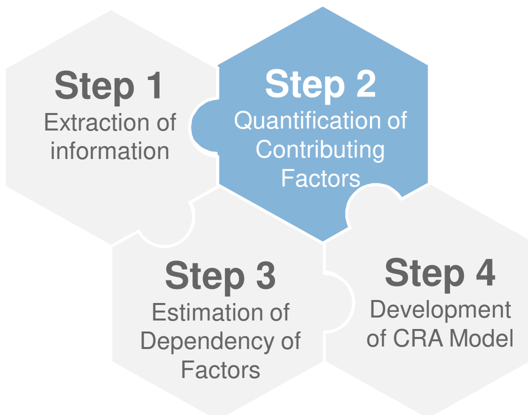
Step 2.

Quantification of Contributing Factors and Updating Data



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Why quantify contributing factors?

- Technical factors are easily quantified in terms of failure rate, failure probabilities, time to next failure *etc*.
- Non-technical factors (such as the contributing factors we identified) rely on expert opinion and are semi-quantitative
- To build an integrated risk assessment model, we want to express non-technical factors in units similar to technical failures
- For technical factors we adopt a well-known method for determining/updating failure data and for non-technical factors we develop a methodology

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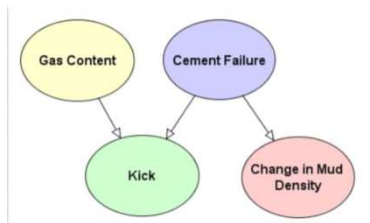
Bayesian method

$$\underbrace{P(A|B)}_{\text{Updated data}} = \frac{P(B|A) \times P(A)}{P(B)}$$

Past data/ observation/evidence

Prior understanding/information

Normalizer



Bayesian network

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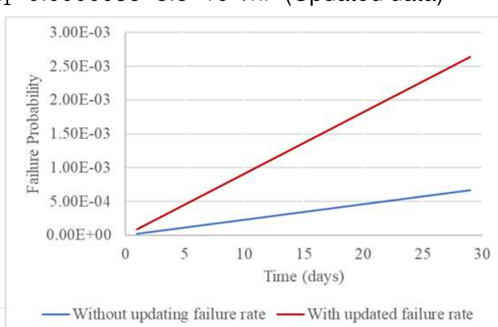
Technical factors: data and updating

- Method for updating failure rate (adopted from Hauge *et al.)*
  - Fail to function on demand = λ_0= 0.97×10^{-6} /hr (Generic data)
  - It was noted that 3 detectors had failed over a period of 6 months
  - $\lambda_1 = \frac{\alpha + x}{\gamma + t}$
  - λ_1=0.0000038=3.8×10^{-6}/hr (Updated data)



Graph showing how updating failure rates can vary our understanding of the probability of failure of an equipment

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Assumptions for quantifying non-technical factors

- Deviations in non-technical factors can occur frequently, but only at certain times, they combine and lead to incidents –such deviations/failures are termed 'critical'
- Their occurrence follows a stochastic (random) process
- Occurrence of 'critical' failures can vary with time – management changes, budget cuts *etc*. can have influence on the failure rate
- Non-technical factors are repairable and time to repair is negligible
- Once a contributing factor fails, it is repaired to a 'same as old' condition

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Operating time between failures

- Our data has dates when each non-technical factor showed failure -from 01/01/2004 to 12/31/2016
- We assume US OCS as a single entity/system
- But operating time varies between incidents, year by year
- Installation date and removal date of a located in US OCS was obtained
- Matlab algorithm developed to calculate cumulative number of days of operation of all operating complexes during a given calendar time

	Date Occurred	Incomplete/Improper JSA or PHA	Inadequate Isolation	Inadequate/Lack of Maintenance	Inadequate/Improper Procedure	Procedural Deviation	Design Flaw	Degradation of Material
1	12/23/2016							
2	12/10/2016						1	
3	7/22/2016	1				1		
4	4/13/2016						1	
5	3/12/2016		1				1	
6	2/13/2016		1	1				
7	12/13/2015							

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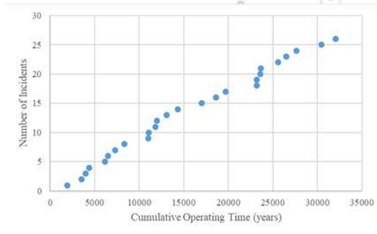
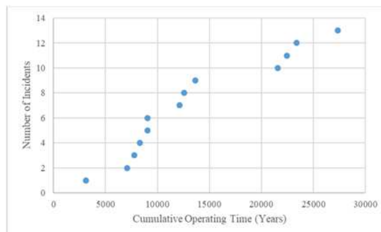
Modeling failure process

- Failure rate varies with time
- We model non-technical factors as following a non-homogenous Poisson process (NHPP)
- From graphs, assumptions of 'same as old' repair (NHPP) seems logical
- Use of distributions allows incorporation of uncertainty in estimation



Procedural Deviation



Inadequate Supervision

Figures showing how failure times can be cluttered over certain periods of time

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Power law for NHPP

- NHPP can be modelled using the Power Law where
  - Rate of occurrence of failure, ROCOF $w(t) = \frac{\alpha}{\beta}\left(\frac{t}{\beta}\right)^{\alpha-1}$
- We want to use the data (evidence) from Step 1 to determine the parameters α and β
- Using Hierarchical Bayesian Analysis:
  - Parameters (α and β) can be estimated from the evidence of past failure times using Bayesian estimation
  - Estimated parameters are then used as priors and plant data are used as evidence to obtain plant specific information
- OpenBUGS© allows us to perform this computation through use of Markov Chain Monte Carlo simulation

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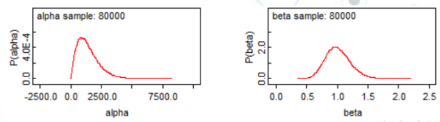
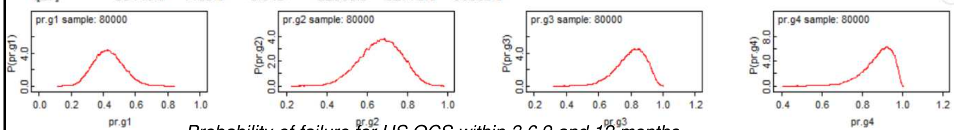
Results: procedural deviation

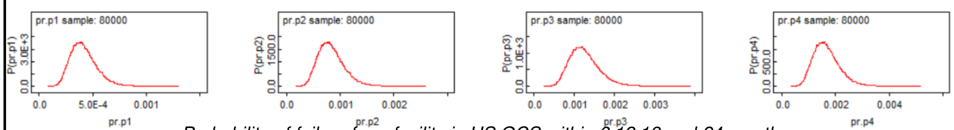
	mean	sd	MC_error	val2.5pc	median	val97.5pc
alpha	1404.0	873.2	10.61	210.6	1237.0	3542.0
beta	1.011	0.2012	0.002349	0.6555	0.9966	1.443
pr.g1	0.4308	0.09022	8.895E-4	0.2667	0.4274	0.6157
pr.g2	0.6679	0.102	0.00101	0.4613	0.6721	0.8533
pr.g3	0.8018	0.08939	8.887E-4	0.6035	0.8123	0.9443
pr.g4	0.8792	0.07177	7.145E-4	0.7079	0.8925	0.979
pr.p1	4.148E-4	1.194E-4	1.168E-6	2.238E-4	4.011E-4	6.859E-4
pr.p2	8.293E-4	2.386E-4	2.336E-6	4.475E-4	8.02E-4	0.001371
pr.p3	0.001244	3.578E-4	3.502E-6	6.712E-4	0.001203	0.002056
pr.p4	0.001658	4.768E-4	4.667E-6	8.948E-4	0.001603	0.002741
t[27]	33140.0	1183.0	8.045	32060.0	32770.0	36350.0



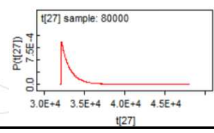
Distribution of parameters α and β



Probability of failure for US OCS within 3,6,9 and 12 months



Probability of failure for a facility in US OCS within 6,12,18,and 24 months



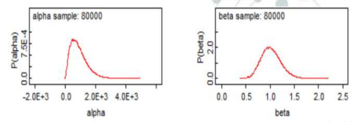
Time to next failure distribution (operating years)

Using near-miss data

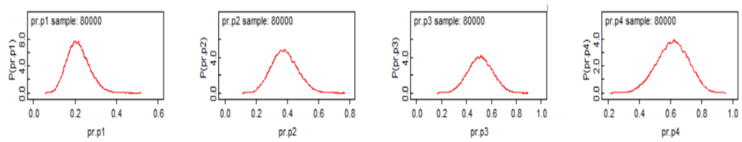
- Since occurrence of major incident in a facility is quite rare, we can use near miss incident investigation findings
- This will enable better understanding of changes in failure rates
- Using the concept of Heinrich's Pyramid, we assume that for 1 major incident, there are 600 near misses
- Then, near misses can be averaged to occur 600 times more frequently (time to failure is divided by 600)

Results with near-miss data: procedural deviation

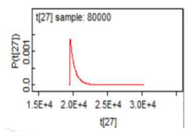
	mean	sd	MC_error	val2.5pc	median	val97.5pc
alpha	880.8	546.2	6.404	138.2	778.2	2200.0
beta	1.02	0.2027	0.002363	0.6622	1.007	1.449
pr.p1	0.2165	0.05381	5.764E-4	0.1229	0.2126	0.3318
pr.p2	0.3833	0.08332	8.983E-4	0.2306	0.38	0.554
pr.p3	0.5124	0.09745	0.001057	0.3247	0.5118	0.7029
pr.p4	0.6128	0.102	0.001111	0.4073	0.6156	0.8023
t[27]	20190.0	752.0	5.382	19500.0	19950.0	22220.0



Distribution of parameters α and β



Probability of failure for a facility in US OCS within 6,12,18,and 24 months



Time to next failure distribution (calendar days)

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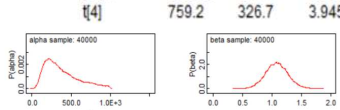
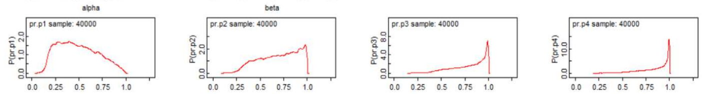
Updating failure rate with plant data

- Assuming observation of Procedural Deviation in investigated near-misses and/or incidents that occurred in 200, 300 and 520 days since the last failure

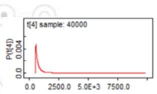
	mean	sd	MC_error	val2.5pc	median	val97.5pc
alpha	376.8	211.9	3.605	97.53	325.2	890.1
beta	1.082	0.1897	0.002466	0.714	1.081	1.463
pr.p1	0.4893	0.2066	0.003242	0.1708	0.4681	0.9011
pr.p2	0.6986	0.204	0.003321	0.3097	0.7212	0.9914
pr.p3	0.8064	0.174	0.002871	0.4227	0.855	0.9993
pr.p4	0.8686	0.144	0.002387	0.5148	0.9252	1.0
t[4]	759.2	326.7	3.945	524.5	655.0	1634.0



Updated distribution of parameters α and β



Updated probability of failure within 6,12,18,and 24 months



Updated time to next failure distribution (calendar days)

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Findings

- We analyzed total 11 non-technical contributing factors
- We found “design flaw” and “improper JSA” improving with time (β<1 indicates ‘reliability growth’)
- Most of the factors need improvement (β>1, ‘ageing’ system (performance deteriorating with time))
- We determined how failure probabilities change with time and performance- thus capturing the plant dynamicity
- Near miss incidents should be investigated to understand where deviations are occurring more – would help with resource management

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Implementation challenges

- Using near miss data
- Incidents reporting system where companies can gather near misses: better reporting will increase the accuracy of the results

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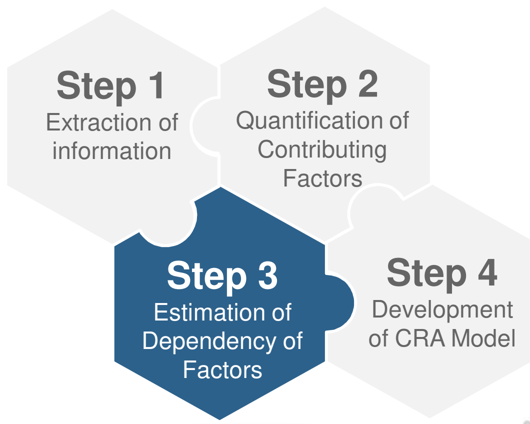
Step 3.

Estimation of Dependency of Contributing Factors



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Combination of contributing factors

- Learning from past incident analysis used to determine how multiple factors depend and interact with each other
- Took leading contributors behind equipment failure
- Counted number of times possible combination of the contributing factors occurred
- Estimated weights of each combination

Combination	Inadequate/Lack of Maintenance	Degradation	Design Flaw	Count	Weight
1	1	1	1	2	0.045
2	1	0	1	2	0.045
3	1	1	0	8	0.182

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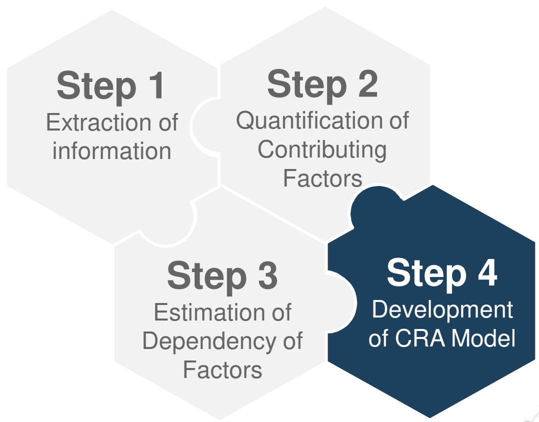
Findings

- Method for capturing the various ways non-technical factors can interact have been shown.
- Same method can be used for other cases such as human error, or non-routine tasks like hot work.
- This will help understanding dependency amongst factors

Implementation challenges

- Gathering greater amount of information will increase the precision of the results
- Considering a large number of contributing factors altogether will increase computational demand
- Weights will enable better understanding of the more lethal combinations

Step 4.
Development of Cumulative Risk Assessment Model



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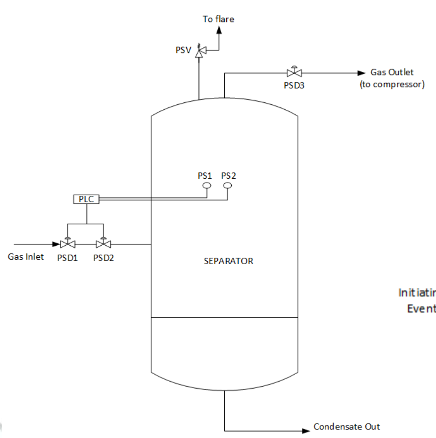
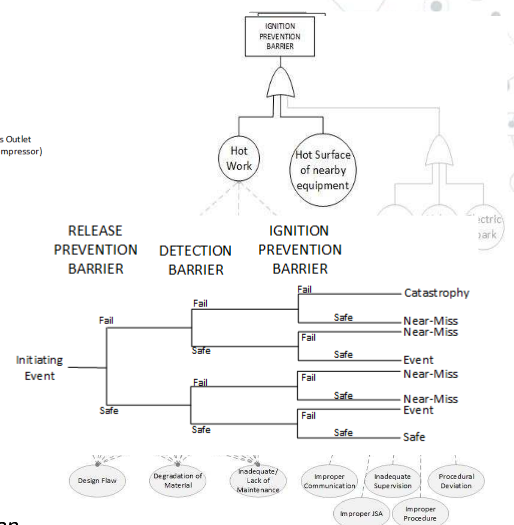
Merging information: Case study

- .



A simplified schematic diagram of an offshore oil-gas separator



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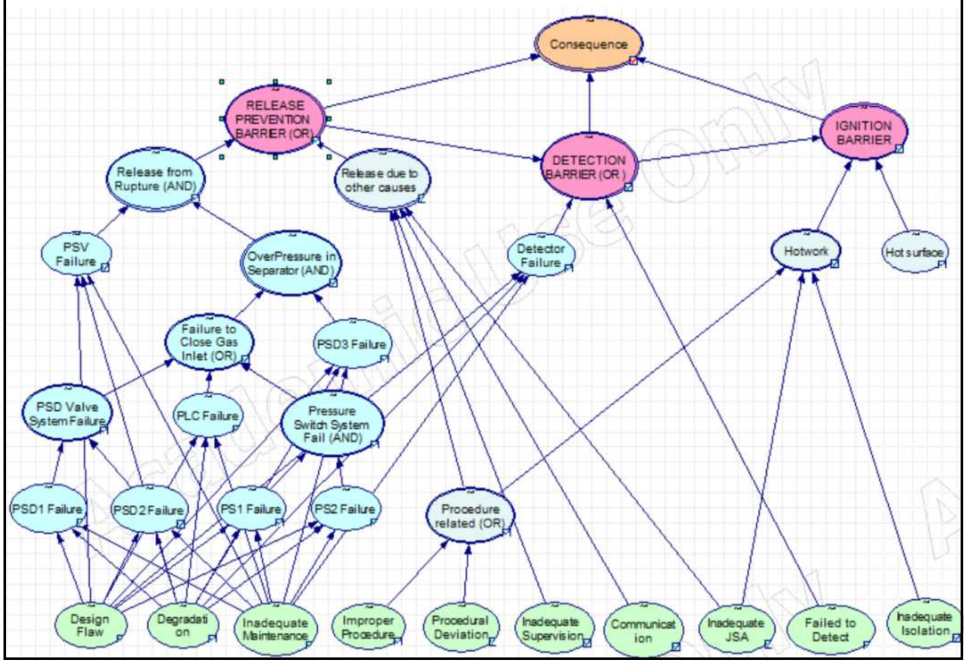
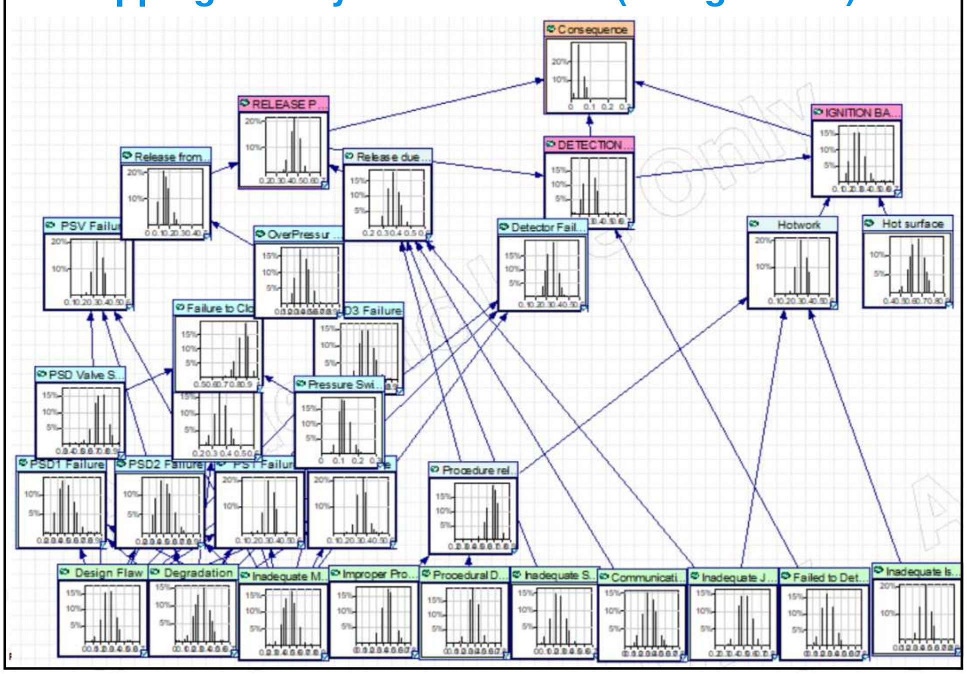
62

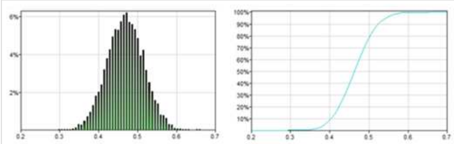
Mapping on Bayesian Network (using GeNIe)



Mapping on Bayesian Network (using GeNIe)



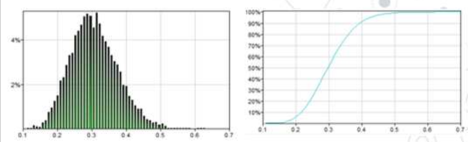
Results with near-miss data



Mean: 0.4683 Minimum: 0.2947

Standard Deviation:0.0475 Maximum: 0.6606

PDF and CDF for Release Prevention Barrier

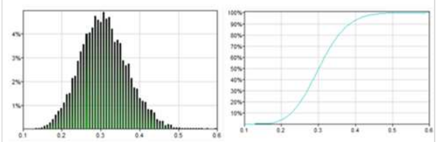


Mean=0.3072 Minimum=0.1115

Standard Deviation=0.0699 Maximum=0.6231

PDF and CDF for Ignition Prevention Barrier

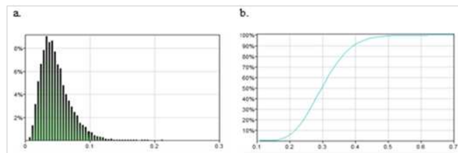
- Mean value indicates probability of failure in the next 1 year



Mean=0.3084 Minimum=0.1299

Standard Deviation=0.0622 Maximum=0.5944

PDF and CDF for Detection Barrier



Mean=0.0476 Minimum=0.0055

Standard Deviation=0.0238 Maximum=0.2115

PDF and CDF for Incident

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Assumed near-misses/incidents

- We assume that in a facility, the 5 incidents with the given contributing factors occur:

Near Miss/Incident	Cumulative time since last incident (days)	Procedural Deviation count	Improper JSA count	Inadequate/Lack of maintenance count
1	**200**	**1**		
2	**300**	**1**		**1**
3	**450**			**1**
4	**520**	**1**	**1**	
5	**680**		**1**	**1**

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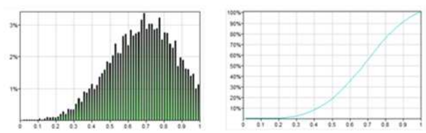
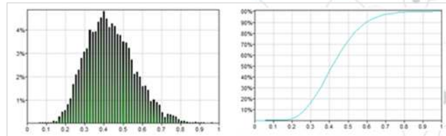
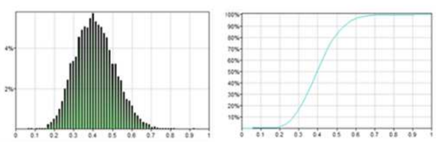
Results with updated data



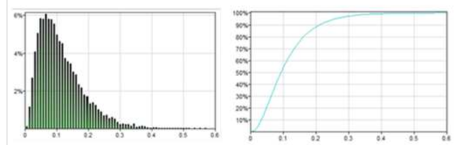
PDF and CDF for Release Prevention Barrier



PDF and CDF for Ignition Prevention Barrier



PDF and CDF for Detection Barrier



PDF and CDF for Incident

- Increase in probabilities indicates organization's performance is worse than industry average

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Findings

- Developed a model using Bayesian Network that **merges** technical and non-technical factors to give cumulative risk
- Results also express the **uncertainties** in the estimation
- Case study showed an increase in the probability of an incident 0.0476 to 0.1160 (~21 years to 8 years)
  - Generic data was made **plant specific**
  - **Dynamicity** of the system can be understood
- **Dependency** of multiple barriers on certain contributing factors can be identified

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68

Implementation

- Bayesian network will show if management decisions can cause an increase in risk
- Data from near misses will show to what extent the system's risk of failure has altered before an incident occurs
- Sensitivity analysis will allow determination of the contributor that has the biggest influence on risk
- Help with budget allocation

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69

4. Conclusions

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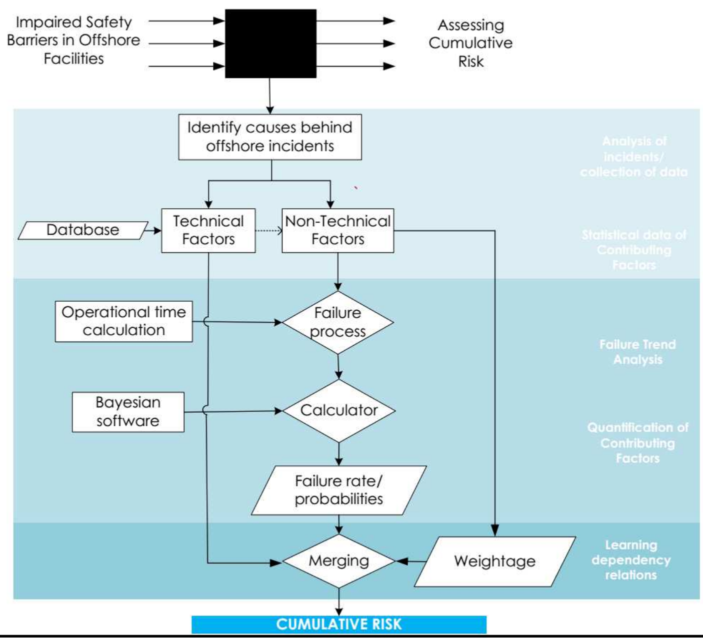
70

Conclusions



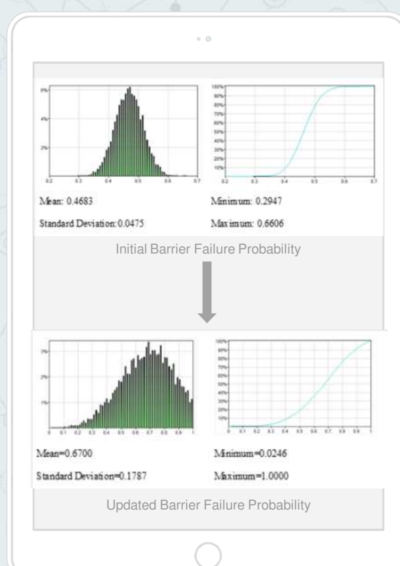
71

Dynamic Risk Estimation

Method developed will allow management to pin-point quickly which issues are increasing the risk of fire.

Budget allocation will be based on better risk information

Previous Risk



New Risk

72

Limitations and Future Work

- Analysis limited to quality of investigation reporting
- A good incident reporting system will improve the precision of the results
- Development of a taxonomy would increase accuracy of results
- Machine learning would make analysis of investigation reports easier and less time consuming
- Future work can extend this to include data from maintenance and inspection records, audit findings *etc.*
- A method for optimization of resource allocation can be developed based on this work to allow management to decide the best possible combination of budget allocation that will give greatest risk reduction
- Consequence analysis can be incorporated to give the total risk value

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Updating knowledge for safer future

Safer offshore, safer environment

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74

“

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

—***George Bernard Shaw***

75

Thank You!

Any questions?

zohrahalim@tamu.edu

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Backup Slides

BSEE investigation reports

Table showing number and time range of district investigation reports and panel investigation reports listed and available via BSEE website (as of October 31, 2017).

	Investigation Reports Listed [16]		Investigation Reports Available [14,15]	
	Time Covered	No. of Reports	Time Covered	No. of Reports
Panel Investigations	01/04/1995-09/19/2017	70	07/20/1983-03/10/2016	101
District Investigations	01/04/1995-09/19/2017	1547	04/11/2003-09/11/2017	859
Total Investigations		**1617**		**960**

BSEE investigation reports

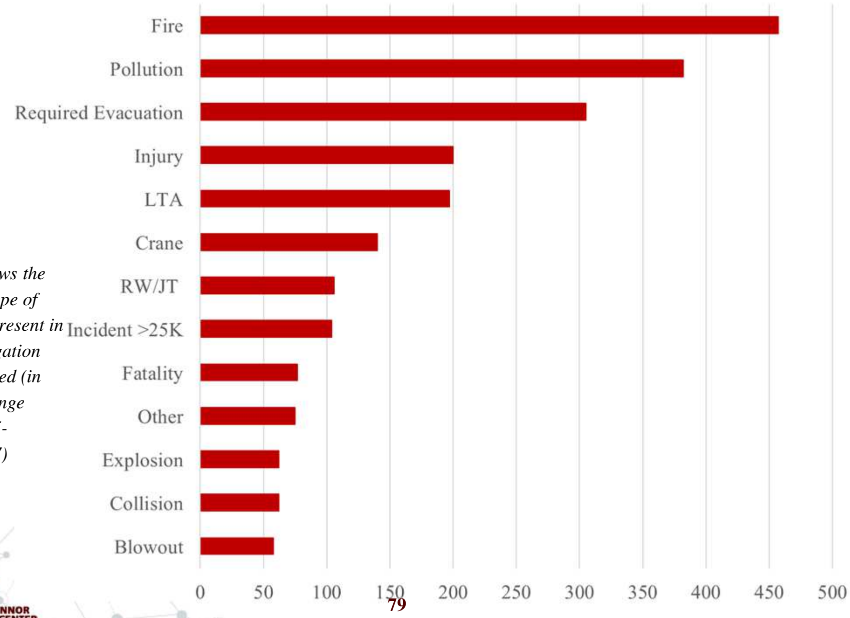

Figure shows the top-most type of incidents present in the investigation reports listed (in the time range 01/04/1995-09/19/2017)

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Sample description

- 457 fire investigations listed
- **137 incidents available and analyzed**
- Consequence of all incidents was fire (+other)
- All District Investigation Reports
- Reports spanned over 12 calendar years (2004-2016 calendar year)

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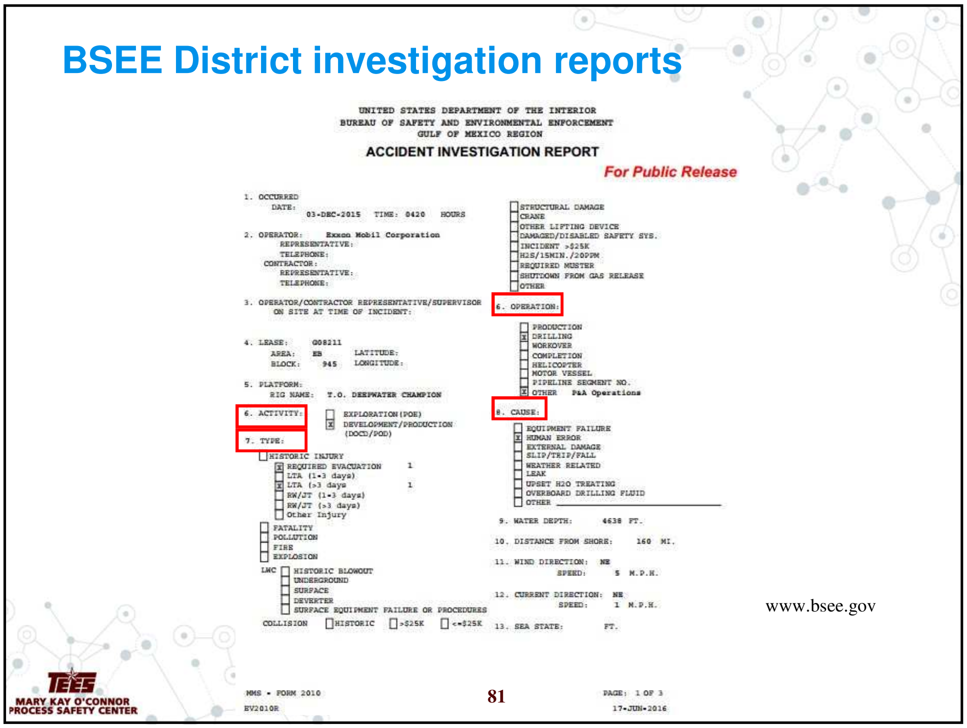
80



BSEE District investigation reports

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF SAFETY AND ENVIRONMENTAL ENFORCEMENT
GULF OF MEXICO REGION

ACCIDENT INVESTIGATION REPORT

For Public Release

1. OCCURRED
   DATE: 03-DEC-2015 TIME: 0420 HOURS
2. OPERATOR: Exxon Mobil Corporation
   REPRESENTATIVE:
   TELEPHONE:
   CONTRACTOR:
   REPRESENTATIVE:
   TELEPHONE:
3. OPERATOR/CONTRACTOR REPRESENTATIVE/SUPERVISOR ON SITE AT TIME OF INCIDENT:
4. LEASE: G08211
   AREA: EB LATITUDE:
   BLOCK: 945 LONGITUDE:
5. PLATFORM:
   RIG NAME: T.O. DEEPWATER CHAMPION
6. ACTIVITY: [ ] EXPLORATION (POE) [X] DEVELOPMENT/PRODUCTION (DOCD/POD)
7. TYPE:
   [ ] HISTORIC INJURY
   [X] REQUIRED EVACUATION 1
   [ ] LTA (1-3 days)
   [X] LTA (>3 days 1
   [ ] RW/JT (1-3 days)
   [ ] RW/JT (>3 days)
   [ ] Other Injury
   [ ] FATALITY
   [ ] POLLUTION
   [ ] FIRE
   [ ] EXPLOSION
   LWC [ ] HISTORIC BLOWOUT
   [ ] UNDERGROUND
   [ ] SURFACE
   [ ] DEVERTER
   [ ] SURFACE EQUIPMENT FAILURE OR PROCEDURES
   COLLISION [ ] HISTORIC [ ] >$25K [ ] <=$25K

[ ] STRUCTURAL DAMAGE
[ ] CRANE
[ ] OTHER LIFTING DEVICE
[ ] DAMAGED/DISABLED SAFETY SYS.
[ ] INCIDENT >$25K
[ ] H2S/15MIN./20PPM
[ ] REQUIRED MUSTER
[ ] SHUTDOWN FROM GAS RELEASE
[ ] OTHER

6. OPERATION:
   [ ] PRODUCTION
   [X] DRILLING
   [ ] WORKOVER
   [ ] COMPLETION
   [ ] HELICOPTER
   [ ] MOTOR VESSEL
   [ ] PIPELINE SEGMENT NO.
   [X] OTHER P&A Operations
8. CAUSE:
   [ ] EQUIPMENT FAILURE
   [X] HUMAN ERROR
   [ ] EXTERNAL DAMAGE
   [ ] SLIP/TRIP/FALL
   [ ] WEATHER RELATED
   [ ] LEAK
   [ ] UPSET H2O TREATING
   [ ] OVERBOARD DRILLING FLUID
   [ ] OTHER
9. WATER DEPTH: 4638 FT.
10. DISTANCE FROM SHORE: 160 MI.
11. WIND DIRECTION: NE
    SPEED: 5 M.P.H.
12. CURRENT DIRECTION: NE
    SPEED: 1 M.P.H.
13. SEA STATE: FT.

MMS - FORM 2010
EV2010R
PAGE: 1 OF 3
17-JUN-2016

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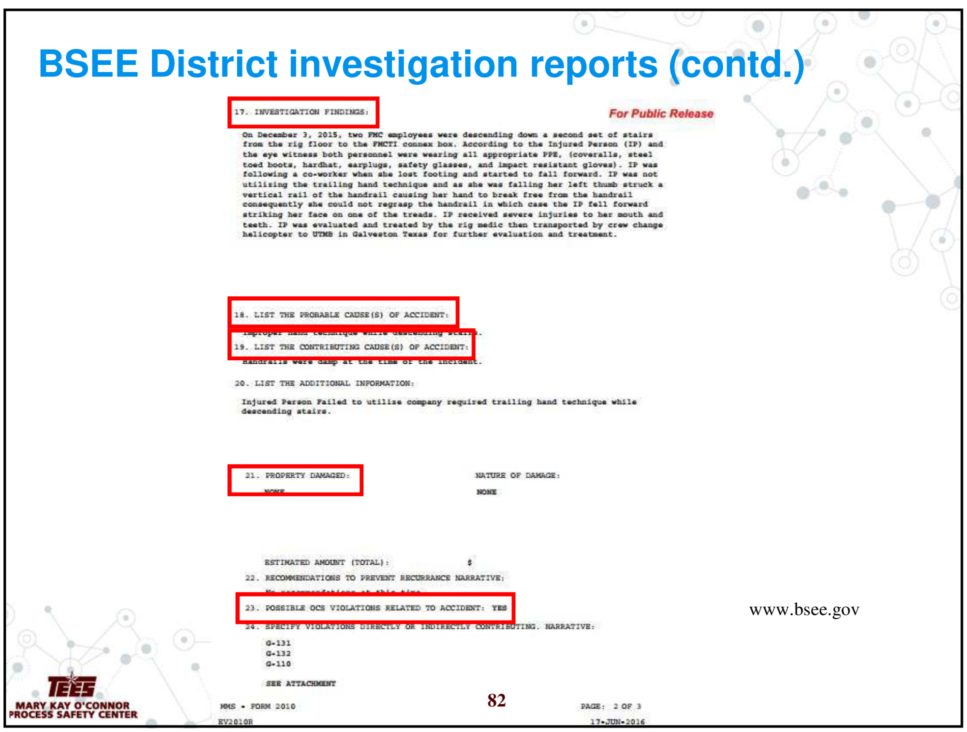
81



BSEE District investigation reports (contd.)

17. INVESTIGATION FINDINGS:

For Public Release

On December 3, 2015, two FMC employees were descending down a second set of stairs from the rig floor to the FMCTI connex box. According to the Injured Person (IP) and the eye witness both personnel were wearing all appropriate PPE, (coveralls, steel toed boots, hardhat, earplugs, safety glasses, and impact resistant gloves). IP was following a co-worker when she lost footing and started to fall forward. IP was not utilizing the trailing hand technique and as she was falling her left thumb struck a vertical rail of the handrail causing her hand to break free from the handrail consequently she could not regrasp the handrail in which case the IP fell forward striking her face on one of the treads. IP received severe injuries to her mouth and teeth. IP was evaluated and treated by the rig medic then transported by crew change helicopter to UTMB in Galveston Texas for further evaluation and treatment.

18. LIST THE PROBABLE CAUSE(S) OF ACCIDENT:
    Improper hand technique while descending stairs.
19. LIST THE CONTRIBUTING CAUSE(S) OF ACCIDENT:
    Handrails were damp at the time of the incident.
20. LIST THE ADDITIONAL INFORMATION:
    Injured Person Failed to utilize company required trailing hand technique while descending stairs.
21. PROPERTY DAMAGED: NONE
    NATURE OF DAMAGE: NONE

ESTIMATED AMOUNT (TOTAL): $

22. RECOMMENDATIONS TO PREVENT RECURRANCE NARRATIVE:
    No recommendations at this time.
23. POSSIBLE OCS VIOLATIONS RELATED TO ACCIDENT: YES
24. SPECIFY VIOLATIONS DIRECTLY OR INDIRECTLY CONTRIBUTING. NARRATIVE:
    G-131
    G-132
    G-110

    SEE ATTACHMENT

MMS - FORM 2010
EV2010R
PAGE: 2 OF 3
17-JUN-2016

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82

Work process at time of incident

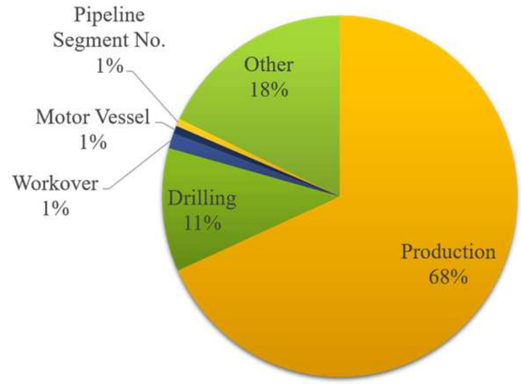

Figure showing type of operation being conducted when fire occurred

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83

Types of incidents reported (2009-2016)

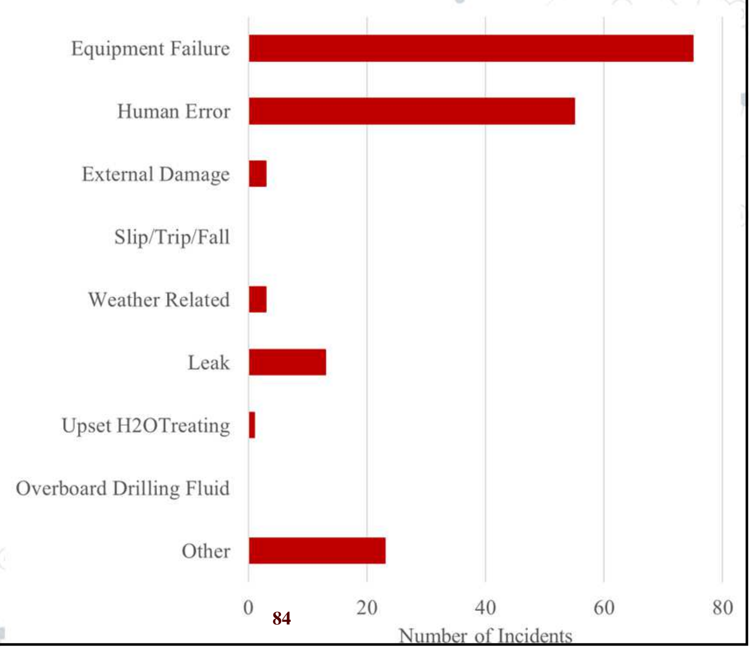

Figure showing the number of times each of the 9 causes were identified by BSEE in the sample 137 fire incidents (2004-2016).

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Factors Identified in Analysis

- Equipment Failure
- Human Error
- Collision/External Damage
- Slip/Trip/Fall
- Natural Cause/Weather Related
- Leak
- Upset H2O Treating
- Overboard Drilling Fluid
- Inadequate Isolation/Missing Physical Barrier
- Inadequate/Improper Procedure
- Violation of Procedure/Procedural Deviation
- Failed to Detect
- Failed to Respond on Time/Delayed Response
- Inadequate Control
- Inadequate/No Training
- Design Flaw
- Corrosion
- Degradation of Material
- Contamination
- Failure Due to Excess Vibration
- Inadequate/Lack of Maintenance
- Improper Inspection
- Improper Installation
- Unsuitable/Improper Equipment
- Use of Improper Material/Parts
- Incomplete/Improper JSA or PHA
- Permit to Work Related
- MOC Related
- Improper Communication
- Inadequate/Improper Supervision
- Improper Storage/Handling
- Impact/ Dropped Object
- Improper mud weight
- Cementing problem/improper cementing
- Other

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Other findings

- Most common places for fire initiation:
  - Compressors (18%)
  - Pipes and hoses (16%)
  - Generators and engines (15%)
- Compressors and pipes usually provided the fuel; engines and generators were ignition sources
- Operations that initiated a fire:
  - Maintenance (33%)
  - Hot work (24%)

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Factors occurring in conjunction with 'Leak'

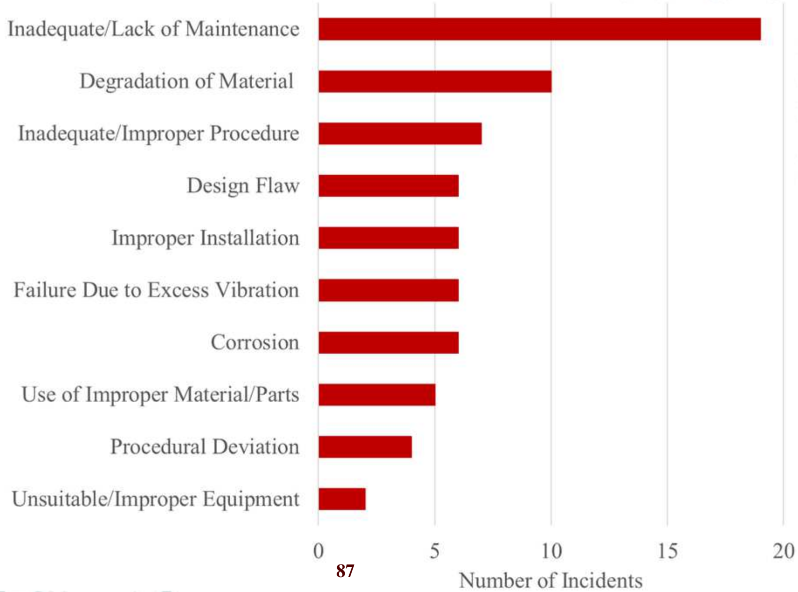

Figure showing the different factors that appeared in conjunction with leaks.

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Limitations of analysis

- Limitations include:
  - Error of non-observation
  - Error of observation
  - Error of processing
- Text mining
  - Requires understanding of what can go wrong
  - Identified some direct causes and superficial information
- Methodology developed to eliminate processing error

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88