Reflections on the recent serious events in the offshore oil and gas sector from a risk assessment perspective with focus on human and organizational factors

Presentation
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Overview
• Background and challenges
• Brief history
• Trends in accidents & incidents
• Trends in modelling of major accidents
• Goal-setting regime
• Life-cycle perspective
• Main regulatory principles
• Modelling practices
• Could risk assessment have prevented Macondo or Gullfaks C?
• Barrier management
• Conclusions
Background

• Serious OO&G accidents since year 2000:
  – Capsize and sinking of Roncador P-36 (Brazil, 2001)
  – Burning blowout on Temsa field (Egypt, 2004)
  – Riser rupture and fire on Bombay High North (India, 2005)
  – Burning blowout on Usumacinta (Mexico, 2007)
  – Blowout on Montara field (Australia, 2009)
  – Burning blowout on Macondo field (US, 2010)
  – Pollution from well leak in Frade project, Campos Basin (Brazil, 2011)
  – Capsizing and sinking of Kolskaya jack-up during tow, (Russia, 2011)
  – Burning blowout on Endeavour jack-up platform (Nigeria, 12)
  – Uncontrolled well leak on Elgin platform in North Sea (UK, 12)
• Also several fatal helicopter accidents, during transit to offshore installations

Recent trends worldwide – offshore

• 2001–10 compared to 1991–2000:
  – Notably fewer major accidents in earlier period
  – Most severe ever, the explosions and fire on Piper Alpha in the North Sea in July 1988 in previous decennium
• Is this total failure of risk management?
• Proof that risk based regulations do not function?
• Virtually all offshore regions are represented
  – Looking to the North Sea, North Atlantic, Norwegian Sea and Barents Sea
    • Most severe accidents occurred some 20 to 30 years ago
    • No severe accidents at all during the latest period
    • Very serious near-misses recently
Risk Level project (N)

- **Objective**
  - Establishing a realistic and jointly agreed picture of trends in HES work
    - In order to support the efforts made by the PSA and the industry to improve the HES level within petroleum operations
- **History**
  - April 2001
    - 1. report issued, for period 1996-2000
  - January 2004
    - Responsibility for HES for offshore & onshore petroleum facilities taken over by Petroleum Safety Authority
  - April 2007
    - 1. report with 8 onshore plants included, based on 2006 data
  - 2010
    - Extension from risk to personnel to risk for spills to sea
- **Regular schedule**
  - Annual reports (risk to personnel) issued in April
  - Separate spill report in September

Risk level project (RNPP)

- **Major hazard risk one element of RNPP**
  - Indicators suggest that major hazard risk has been reduced since year 2000
    - Precursor based indicators
    - Proactive (‘leading’) indicators based on barrier elements
  - On the other hand
    - Some installations are dramatically worse than average
    - Some are also exceptionally good
    - Large differences is a challenge for authorities
  - Modeling based on risk analysis R&D
Offshore risk management – success story?

- Impression
  - Norwegian & UK systems have been successful
    - Confirmed by Presidential Commission (US)
  - Large accidents have been avoided in NW Europe for long time
    - UK: after 1988
    - Norway: after 1985
- Is the situation so glorious as may be inferred from this?

Perspective: Alexander Kielland To Macondo

- Capsize and sinking of Alexander Kielland (Norway, 1980)
- Burning blowout on Macondo field (US, 2010)
- 30 years separation:
  - Capsize of the flotel Alexander L. Kielland in Norwegian North Sea
  - Burning blowout on Deep Water Horizon in US GoM
- Encompasses the development and use of risk assessments in risk management offshore
Brief history: Use of risk analysis (N)

- Early start in late 1970s
- Regulatory requirement since 1981
- Approach initially based on practices in nuclear power plants
  - Usually no 3rd party personnel risk to consider offshore
- Development over time away from nuclear PSA approach
- QRA studies are not in the public domain
- Few cases where ethical controversies are known

- Offshore QRA
  - Focus on consequences (ignited HC leaks)
  - Limited focus on barrier failure probabilities
  - Causes of initiating events traditionally not covered

- NPP PSA
  - Focus on probability of defined scenarios
  - High focus on common mode & cause failures, etc
  - “Living PSA”

Brief history: Use of risk analysis

- Main application of risk assessments in the Norwegian industry in the 1980ties and 1990ties
  - Design tool, in order ensure that new installations had sufficient capabilities
    - To prevent major accidents and protect personnel in the case of such accidents
    - Significant investments in consequence modelling software tools, most well known is FLACS code
Brief history: Use of risk analysis

- Official inquiry by Lord Cullen in the UK, following Piper Alpha accident in 1988
  - Recommended that QRAs should be introduced into UK legislation
    - Corresponding to the way as in Norway nearly 10 years previously
  - Parallel focus on documentation through Safety Case documents

- Safety case
  - Primarily a tool for risk management in relation to existing installations
    - Main focus on consequences, layout and mitigation barriers
  - Similar approaches also adopted by several other countries (Denmark, Canada, Australia,..) & Shell on a worldwide scale ('HSE case')

- Many countries, most notably US, still have prescriptive regulations
Events that made marks on history

- NPPs
  - Three Mile Island (1979)
  - Chernobyl (1986)
  - Fukushima (2011)
- Accidents that have had similar extensive impact for the offshore operations:
  - Capsize of Flotel Alexander L. Kielland, 1980
  - Capsize of Mobile Offshore Drilling Unit Ocean Ranger, ‘82
  - Explosion & fire on fixed production platform Piper A, ‘88
  - Burning blowout on Deep Water Horizon mobile drilling unit, 2010

Impacts on Standards and Practices

- Capsize of the flotel Alexander L Kielland
  - Basic safety training for personnel
  - Use of conventional lifeboats in severe weather
  - Construction safety
  - Barriers to prevent rapid capsizing following major structural damage
Impacts on Standards and Practices

• Capsize of drilling rig Ocean Ranger
  - Improvement of ballast system flexibility for stabilizing the unit in high inclination angles
  - Training of ballast operators
  - Evacuation during severe weather conditions
  - Rescue of survivors following evacuation in severe weather

• Explosion and fire on Piper Alpha
  - Active fire protection
  - Passive fire protection
  - Protection of Temporary Refuge (shelter area)
  - Barriers against high inventories in pipelines
  - Compliance with procedures & documentation
Trends in offshore QRAs (10–15 years)

- Very limited further development
  - Some further development of consequence tools
  - Precursor data and barrier performance data through RNNP (N)
- Development of tools and methods for incorporation of
  - Causes of initiating events within HOF envelop
    - Collisions with offshore vessels
    - HC leaks

Overall purpose
FPSO Operational Safety Project

- Develop models and tools for predictive human reliability analysis
- Test out methodology on selected case studies
- Illustrate results that may be obtained
Objectives

- Demonstrate importance of HOF collision risk
- Identify and evaluate the important HOF factors
- Propose potential risk reduction measures relating to HOF

Contractors:
- NTNU
- SINTEF

Sponsors:
- ExxonMobil
- HSE
- Statoil
- Navion

Importance

- Several incidents 1996–2001
- Low velocity impacts (high mass, up to 30 MJ)
- Cargo penetration unlikely
- Accident chain may imply very severe consequences
- After 2002, 2–3 minor accidents
Comparison
Experienced times and maximum times available

Recovery action initiation

Time to stop

0 60 120 180 240 300 360

50 m distance
80 m distance
150 m distance

Time to collision if no action is taken

Risk Modelling, Integration of Organisational, Human and Technical factors (Risk_OMT)

- Ambitions for the Risk_OMT programme:
  - Extension of verification of barrier performance
    • From existing technical focus into a focus where operational barriers have similar weight
  - Provide sound quantitative basis
    • for analysis of operational risk reducing measures
  - Learn how the best managed installations
    • are achieving performance of operational barriers
  - Propose key performance indicators
    • enable identification proactively when operational conditions are deviating from a high standard

R&D PARTNERS:
- US, NTNU, SINTEF, FFI

Project sponsors (2007-11):
- Norwegian Research Council
Dependencies

- Change management
- Communication
- Procedures and documentation
- Physical working environment and workload
- Competence

Life cycle perspective

- The life cycle perspective is most obvious in Norwegian legislation, which apply for all phases of petroleum activity.
- UK legislation has the same perspective.
- The Norwegian legislation may be described as functional, risk-based (or risk informed):
  - Based on use of risk assessments in all phases.
Offshore petroleum: Use of risk analysis

- QRA (quantitative risk analysis)
  - New development
    - Concept selection
    - Concept optimization
    - Engineering
    - Fabrication
    - Pre start-up ('as built')
  - Operations phase
    - When modifications are implemented
    - Otherwise regularly (say every 3-5 years)
    - Prior to start of decommissioning
- Qualitative risk analysis
  - As design tool (HAZOP, etc)
  - As operational tool (HAZID, etc)

Goal-setting regime

- Implications of goal-setting approach:
  - Industry has more flexibility vis-à-vis fulfilling regulations & finding optimum solutions
  - Preventive and protective systems and actions may be tailored to relevant hazards
  - Models need to be available to distinguish between different levels of threats, and to tailor the solutions to the circumstances
ISO 31000 – Risk Management

- Also the basis for:
  - NORSOK Standard Z-013 Risk analysis and emergency preparedness assessment

Misuse of risk analysis in petroleum sector

- PSA:
  - Risk analysis primary use to identify & assess risk reducing measures in ALARP context
  - Risk analysis shall not be used to ‘prove’ acceptability of deviation from laws, regulations, standards, common practice, etc.

- HSE [UK] has made similar remarks
- Misuse
  - Was an issue in 1980s, with limited QRA experience
  - Reiterated warning in 2007
Robust regulations?

- Combination of internal control and risk-informed regulations appear to be fragile and far from robust combination for
  - Industry
  - Authorities

- No apparent focus in research

Could risk assessment prevented Macondo?

- Presidential Commission makes reference to North Sea legislation as possible model for US
  - ≈ 2 years after the accident:
    - no change so far
  - Some are sceptical that anything will change
Could risk assessment prevented Macondo?

• Reflections on this question
  – PSA has confirmed that Macondo accident could have occurred in Norwegian sector
  – Several incidents/accidents during 2004–10
    • Full blown subsea gas blowout in Nov. ’04 on Snorre A (Norwegian North Sea)
      – Lack of compliance with procedures one root cause
      – Also one of success factors of the well killing operations

Could risk assessment prevented Macondo?

• One of the common factors in recent well associated incidents & accidents:
  – Lack of proper risk assessment to
    • Identify criticality of various factors and deviations from plans & procedures that have to be made

• Common factor with the Macondo accident
  – Failure to assess risk as basis for MOC one crucial failure

• Effective management of major accident risk is strongly dependent on
  – Adequate modelling (i.e. insight) of hazard mechanisms
  – Stringent management of barriers throughout field life
    • Crucial factor in Montara accident
Could risk indicators prevented Macondo?

- Parallel with Texas City refinery explosion, where occupational injury statistics had been used to monitor major hazard risk
- Deepwater Horizon had been 7 years without significant occupational injuries
- Norwegian petroleum industry (RNNP)
  - Indicator for blowout risk based on occurrence of kicks (influx from high pressure zones into wellbore)
    - Typically 1 per 20 regular wells drilled
    - Deepwater wells (possibly up to 1 per 3 wells)
    - Insufficient to monitor performance in well drilling

Could risk indicators prevented Macondo?

- Study in recent R&D project has shown:
  - Blowout probability strongly influenced by
    - Inadequate planning of well operations
    - Inadequate management of change during drilling operations
- How should indicators be defined?
- Even if we had indicators
  - Would they be able to identify in time?
    - Failures of well planning
    - Failures during management of change during drilling operations
Could risk indicators prevented Macondo?

• Reference to Snorre A gas blowout (2004)
  – Undetected failures
    • Reentry into well planned without realizing leaks in casing
    • Risk assessment bypassed due to lack of resources
    • Failures were not detected before operations started
  – Unignited gas blowout
    • No injuries, no spill
    • Top kill within few hours, before ignition
      – Ignition could have caused total loss of installation and very extensive spills

• No indicators were able to identify well planning failures
• Is indicators the right way to go?

Could risk indicators prevented Macondo?

• Skogdalen et al.: possible use of major accident risk indicators to prevent accidents like Macondo
  – Many essential barrier elements are operational
    • Evaluation of the negative pressure test, which is one of the examples of the crucial misinterpretation of the tests
  – On every occasion that the drilling crew were supposed to make decisions balancing efficiency and risk (Pres. Com.)
    • Decided in favour of efficiency
      – thereby each time increasing the risk of a blowout
      – at the end failed to detect indications that there was a serious problem under development

• It appears very demanding to develop indicators that could have picked up this development
Could risk assessment prevented Gullfaks C?

- Lack of risk assessment identified as 1 root cause
  - PSA: why was risk assessments omitted?
- IRIS report identified significant management deficiencies
  - Limits Statoil’s ability to learn from accidents & incidents
- Investigation practices are also counterproductive with respect to learning
- More important than risk assessment:
  - Significant improvements to management attitudes & supervision
- A-standard appears to have significant effect
  - Reduced frequency of HC leaks in 2012

Risk assessment of drilling and well operations

- PSA has repeatedly claimed that risk assessment tools used by the Norwegian petroleum industry are not suitable for operational decision-making
  - Survey (PSA, 2009–10) pointed to need for further development of risk analysis tools
    - Usable as input to day-to-day decisions on installations; minor modifications, maintenance and interventions
    - Same observation would be applicable also for drilling operations
- Large difference between the NPPs and offshore installations with respect to development of online risk monitoring
Risk assessment for operational decision-making

- Simplistic or detailed modeling?
- Illustration
  - Decisions on how to install long process lines
    - Alt. A: Welding work
      - implies increased ignition risk during installation
    - Alt. B: ‘Cold’ installation methods, flanged connections
      - may increase leak probability over remaining life cycle
- Can robust decisions be made without detailed modeling?

Risk assessment of drilling and well operations

- Online risk monitoring for management of operations, maintenance and modifications to facilitate decisions relating to:
  - When a leaking valve needs to be repaired (example)
    - Whether it needs to done immediately in order to control the major accident risk
    - Whether it can wait for some time for the next scheduled plant shutdown
- Online risk monitoring of drilling and well operations is altogether another league
  - Models are not available at all
  - Extensive research effort is needed to develop suitable models
    - Mainly in the HOF field!
Barrier management

- PSA in follow-up after the Macondo blowout proposed also development of a scheme for barrier management
- Barrier failures were also obvious on the Deep Water Horizon mobile drilling rig, such as failure of blowout preventer (BOP)
- Lack of proper management of barriers is also common in the Norwegian industry
  - Poor RNNP barrier data year after year
  - HOF improvement in LOC data

Barrier management

- Management of barriers (ref. PSA) dependent on proper modelling in planning phase
  - Implies that inadequacy of risk models for drilling and well operations will also prevent the basis for barrier management to be established
- Lack of proper risk models will also limit how well risk indicators could be developed
Conclusions

• Prevention of major accidents most effectively through risk-informed decision-making
  – US & others should follow after UK & Norway

• Probably not a coincidence that severe accidents and incidents
  – Have occurred worldwide during the last ten years
  – Not in NW Europe

Conclusions

• Threat from EU to ‘throw out’ all the good experience in UK and Norway
  – Directive proposal apparently mainly aimed at environmental spill protection

• Step back from risk-informed to compliance basis

• Industry is probably partly to blame
  – No focus for many years to develop suitable risk based tools, especially for drilling and well operations
Conclusions

• Modelling of barrier performance is area where substantial improvement is needed
  – Grossly inadequate, especially for drilling
  – Operational barriers extra challenge

• Improvement of risk-informed management of major hazard risk in day-to-day decision-making

• Operational barrier elements the main challenge

Conclusions

• Can major accidents be eliminated?
  – No, one can occur tomorrow even if the probability is very low

• Risk-informed decision-making more advanced for process plant operation
  – Even in this area we have identified significant development needs
  – Drilling and well operations less well developed

• Possibility to learn from NPPs