Reflections on the Gulf of Mexico disaster and other serious events in the offshore oil and gas sector from a risk assessment and risk management perspective

Keynote presentation
Professor Jan Erik Vinnem
University of Stavanger
jan.erik.vinnem@preventor.no

Universitetet
i Stavanger

PSAM11
ESREL 2012
25 - 29 June 2012, Helsinki, Finland
Nordic Footprints
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?
• 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
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

www.ptil.no/rnnp
Risk level project (RNNP)

• Major hazard risk one element of RNNP
  – 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
Brief history: Use of risk analysis

• 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
  – Evacuation during severe weather conditions
  – Rescue of survivors following evacuation in severe weather
Impacts on Standards and Practices

• 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
    • HC leaks
    • Collisions with offshore vessels
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

Tandem loading configuration
Objectives

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

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

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

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

It's all about work practice…

Probability of causing leak through ops error
Use of Qualitative Studies

• Use of risk assessments in practice is strongly influenced by the use of qualitative studies for various purposes:
  – Hazard and Operability Study (HAZOP)
  – Safety and Operability Study (SAFOP)
  – Safe Job Analysis (SJA)
  – Preliminary Hazard Analysis (PHA)
  – Failure Mode and Effect Analysis (FMEA)

• Majority of resources to risk in lifetime
  – Insight into accident causation, prevention & mitigation
  – Motivating personnel involved in operations

• QRA main interest in remainder of presentation
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

Risk management process

6.3 Establishing the context

6.4 Risk assessment

6.4.2 Risk identification

6.4.3 Risk analysis

6.4.4 Risk evaluation

6.5 Risk treatment

6.6 Monitoring and review

6.2 Communication and consultation

- Also the basis for:
  - NORSOK Standard Z-013 Risk analysis and emergency preparedness assessment
Main principles for HES legislation in Norway

• Internal control
• Functional, risk based regulations

• Initially implemented in petroleum sector
  – Considered to function well under NPD/PSA jurisdiction

• Adapted over time to societal safety in general
  – Does it function correspondingly well in this context?
  – No research appears to have looked at this
Internal control as basic principle

• Basic principle in HES regulations in Norway
  – Shall ensure that the activities are planned, organized, executed and maintained in accordance with applicable requirements

• Based on experience in petroleum sector, adopted in several other areas of societal HES
  – Good experience in petroleum sector
Internal control – challenges

• Internal control implies
  – Enterprises are the primary responsible for ensuring that requirements are adhered to, including laws and regulations

• Demanding control principle
  – Demands a technically competent and administratively strong authority
  – Most successful with enterprises with high competence level and high integrity
Experience with risk based regulations

- Petroleum industry
  - Mainly successful, some occasional challenges
  - Warning letter from PSA to all parties in 2007
    - Warnings about increasing trend of misuse
- Demanding approach, for enterprise, supervisory authority and public
  - Risavika LNG plant (N): total failure of risk based regulation
    - Severe flaws in enterprise’s HES management
    - Unethical behaviour
    - None of the supervisory authorities have rectified defects
  - Several cases when public meets risk-informed regulations are challenging
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
Modelling practices

• Hydrocarbon hazards
  – Causes of initiating events
  – Barrier systems reliability and availability
Modelling practices

- Barrier
- Initiating events
- Incident
- Causes
- Consequences
- Risk Influencing Factors
- Technology
- Organisation
- People

Source: Statoil
Modelling practices

- Hydrocarbon hazards
  - Causes of initiating events
  - Barrier systems reliability and availability
  - Fire & explosion load modelling
  - Event sequences and escalation
  - Structural fire & explosion response
  - Human fire & explosion response
  - Fatality risk
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
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?

  - 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
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 be 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
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 (PSA)
Barrier life cycle perspective

Planning
in order to comply with requirements to barriers in all life cycle phases

Implement improvements

Well founded layouts and design as well as safe operation

Evaluate results

Implement in operations phase
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

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