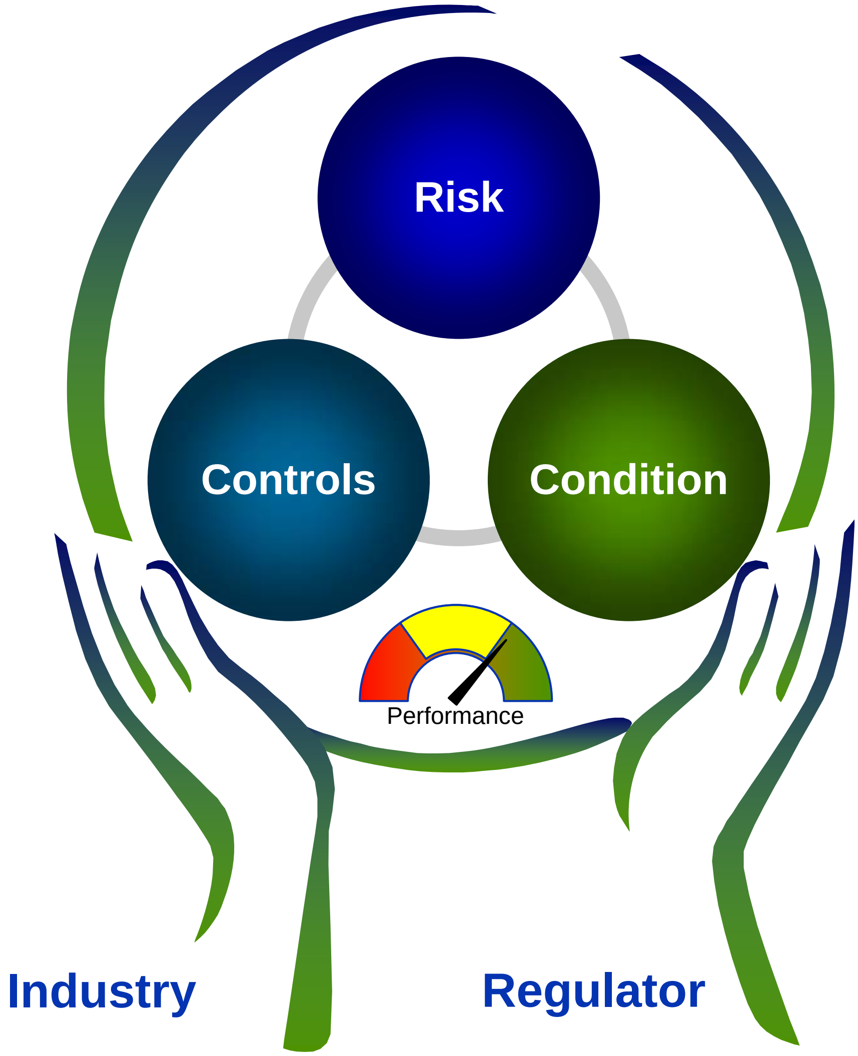

Key Aspects of an Effective U.S. Offshore Safety Regime

DET NORSKE VERITAS

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1. Introduction

Major accidents lead to a review and revision of current practices and regulations with the objective of avoiding similar or other major accidents in the future. This also appears to be the case after the tragic Deepwater Horizon blow-out accident and subsequent oil spill. This paper presents DNV´s view on key aspects of an effective offshore safety[1] regime. The paper is meant as a contribution to the on-going discussion on how to improve safety and environmental protection during offshore oil and gas exploration, development and production. The paper supports and complements the recommendation for a more systematic approach to safety and environment in the U.S. Department of the Interior (DOI) report on "Increased Safety Measures for Energy Development on the Outer Continental Shelf" (May 27, 2010).

DNV[2] believes that a *step change* can be achieved with respect to prevention and mitigation of major accidents through an effective and efficient safety regime for offshore energy exploration, development and production. Such a safety regime must be risk-informed, balancing the inherent risks with the benefits for society and must possess the following characteristics discussed in this paper

- Performance-based supplemented by prescriptive regulation
- Consideration of technology, organization and people
- Clear roles and responsibilities
- Enforced identification, reduction and control of risks
- Shared performance monitoring
- Practical and economic feasibility
- Balance between risk, control and condition

DNV has world wide experience within risk management in the offshore energy and maritime industries. DNV advises regulators on offshore safety regulation as well as executing key functions on behalf of authorities and industry in order to safeguard life, property and the environment. This paper does not present the many ways in which the key aspects could be implemented within law and regulation or how they are effectively institutionalized, or which roles are best managed by governmental agencies and which by

[1] Safety in this paper often covers all aspects related to health, safety and the environment (HSE)
[2] Det Norske Veritas (www.dnv.com) is a global foundation with the purpose of safeguarding life, property and the environment. DNV is the leading company for oil & gas risk assessment globally. It was founded in 1864 in Norway and currently has 9.000 employees, of which about 10% are based in North America. See also Appendix II.

independent or private organizations. The paper does, however, highlight issues and methodologies that DNV believe regulators should take into account when promulgating new legislation.

2. Objective of an offshore safety regime

Oil and gas will constitute the major part of the U.S. energy supply in the foreseeable future despite on-going and needed efforts in developing renewable and other alternative energy sources to meet our energy demand and limit carbon emissions. In addition, deep water exploration and production of oil and gas will continue to be a vital part of our oil and gas supply. Because of this, additional focus on managing risk of deep water activities is needed to prevent consequences such as those from the Deepwater Horizon accident.

Following a major accident we have an obligation to review and revise as needed the offshore safety regime under which oil exploration and production takes place with the objective to

- Ensure that exploration and production activity is done safely and in a sustainable manner, and
- Assure all stakeholders – foremost the public – that activities that pose a threat to life, environment and property are properly controlled

DNV believes that a safety regime for offshore energy exploration and production must ensure that

- Life, environment and property are protected in an effective, consistent, transparent and predictable way; both for those directly affected and involved in offshore operations, but also for those otherwise affected by an accident, such as fisheries, recreation and the whole ecosystem
- Risks are properly evaluated and all prevention and mitigation measures are identified
- Control measures are implemented and maintained by all parties in accordance with mandatory risk assessments as well as what is prescribed by regulation
- Conditions of safeguards, facilities, procedures, personnel and organizations are continuously monitored throughout the lifetime for proper functioning and compliance with all regulatory requirements and to assure that risks do not increase
- Technical innovation and efficiency improvements can be implemented safely and responsibly

3. Performance-based supplemented by prescriptive regulation

The safety regime must benefit from all learning of the past. This is the traditional way of developing safety regulations where previous events lead to new knowledge and additional regulation that prescribes a set of requirements for industry to follow. In most cases, however, regulators and industry do not regularly revise and upgrade procedures, rules and regulations, as the collective knowledge of how to operate safely increases (e.g. Baker Panel[3] findings after Texas City). More often, a major disaster becomes the trigger to update regulations that have been proven to be insufficient.

Every major accident at sea has been followed by new regulation, from maritime oil spill accidents such as Exxon Valdez, Erika and Prestige to offshore oil and gas accidents such as Alexander Kielland, Piper Alpha and now Deepwater Horizon. The same is the case in the chemical process industry where accidents in Bhopal, Seveso, Pasadena Texas and Texas City led to new US and EU regulations. The potential weakness from such regulatory development is that issues of the moment rather than long term sound policy become dominant and that all focus is on the specific event and root causes with insufficient focus on other possible, future hazards.

An offshore safety regime based on prescriptive regulation has the advantage of being relatively easy and simple to implement and follow up but has the weakness that it may not prevent new types of accidents that may appear in the future and it often prevents innovation due to its specific, prescriptive rules and

[3] The Baker Panel was established to investigate safety management systems and safety culture after the Texas City disaster – they laid out many important concepts for enhanced major accident prevention

requirements. It may also limit operators' dedication and understanding of responsibility as well as proactive initiatives to increase the safety level beyond compliance. This is particularly important in the deep water offshore arena where new technologies and techniques to improve production and safety and also reduce costs are being constantly developed, but by their nature may introduce potential new risks.

To be able to account for new types of events and to allow for needed innovation and new technology in the future, performance-based (also referred to as functional-based or goal-based) safety regimes have been introduced in several countries. In these, performance requirements and acceptance criteria are specified and industry must document that their specific solutions meet such requirements, e.g. in terms of acceptable risk levels. The advantage of performance-based regulation is that solutions for the problem at hand can be developed free of specific prescriptions. The regulation will include comprehensive safety – or HSE – cases that document how all risks (including novel risks) for the specific facility, operational conditions and location will be prevented or mitigated. A challenge of a pure performance-based regulation is that it may require more analysis and documentation to be done in each individual case to verify that performance goals are met. It also requires a competent and active regulator.

The current safety regime for the U.S. Gulf of Mexico is largely a prescriptive regulation with no requirement for safety cases[4] to be performed. The offshore safety regimes in the UK and Norway, for example, are of the performance-based type where safety cases (UK) or detailed risk assessments (Norway) must be presented to the authorities who review and accept - rather than approve - these before implementation. Once accepted, operations not in conformance with the safety case is an offence.

DNV believes that an offshore safety regime based on a performance-based regulation requiring safety cases including risk assessments *supplemented* by required or recommended specific prescriptive regulation for *selected* areas is the most effective regime model. Areas that may be addressed by prescriptive regulation are typical facilities, components and situations where experience exists. The prescriptive regulation may include specific requirements supplemented e.g. by API standards and class societies such as DNV Offshore Codes.

The safety regime must ensure a safe operation of the offshore facility throughout its lifetime. The safety case performed at the design stage must be implemented in the actual operation of the offshore installation and not just end as a document on a bookshelf. Furthermore, the offshore installation may be modified, it will degrade over time, external loading conditions on structure or process system may change, and the operator and crew may change. Each such change of condition must be monitored and documented as a safety case update as part of the regulated process for ensuring a safe operation.

4. Consideration of technology, organization and people

A complex system such as an offshore drilling or production platform performs safely and reliably only when

1. The technical facility is fit for purpose and works as intended
2. The people operating the facility are trained and competent, also as regards safety culture, and
3. The organization is defined so decisions are made and safe procedures are followed as planned

Within chemical process plants these aspects are often referred to as plant, process and people which all must be fit for purpose and performing accordingly for the process plant to perform safely.

When root causes are identified for major accidents, it generally turns out to be a combination of several factors that lead to the accident – and often a combination of technical, human and organizational failures. Even when it at first appears that it was a technology failure, the root cause analysis may reveal that organizational or human failures e.g. during modifications or maintenance in reality lead to the failure.

[4] A Safety Case is a documented, facility specific, safety and environmental program that identifies all hazards, estimates risks and demonstrates how these are prevented or mitigated to a stringent target level of safety, merging both prescriptive and facility specific requirements. All safeguards are documented, their required performance defined, owners assigned, and means to keep functional at all times specified (e.g. maintenance, competence, etc), and providing a transparent means to verify the conditions.

Organizational and human factors are the dominant root cause factors and together often estimated to constitute up to 80% of the causes for major accidents.

In summary, it is critical that an offshore safety regime properly accounts for technological, organizational and human factor defenses – or barriers[5] – in the prevention and mitigation of accidents throughout the lifetime of the offshore installation.

5. Clear roles and responsibilities

An effective offshore safety regime must ensure that clear roles and responsibilities are established between all parties involved. In particular, the role and responsibility between authority and operator is important. The performance-based regime has been preferred by a number of authorities not least because of its very clear split of responsibilities, where authorities define performance goals and acceptance criteria and the operator has the responsibility to ensure that these performance goals are met. The aim is to force the operator and contractors to take an active role and not lean on authorities to ensure safety. In such a regime the authorities will normally not approve the operator's plans but only review and accept them.

In a prescriptive regime the authorities define implicitly the performance by prescriptive requirements and will furthermore typically approve the operator's plans, in some cases including detailed operations. Although the operator normally will be defined in the regulation to carry the liability for the operation, matters may become unclear if something goes wrong and the authorities have both given specific requirements for the facilities and operation plans as well as approved their implementation. Also, the responsibilities between parties may also vary between different pieces of the regulation. The choice of the performance-based model is therefore natural when authorities want to minimize own risk and liability.

6. Enforced identification, reduction and control of risks

DNV believes that risks such as those related to offshore drilling and operation can only be properly managed if the risks are known and understood by the operator (and subcontractors to operator) of the facility. Therefore, a key element in an offshore safety regime is that all parties are required to take an active role on undertaking holistic risk assessments for a specific installation through which preventive and mitigating means are identified and where all factors mentioned above are included in the safety and environmental models. Furthermore, the regime must ensure that such risk management is maintained throughout the life of the installation and continuously kept up to date to prevent deterioration of barriers that prevent and mitigate risks.

DNV believes that the frequency of major accidents only can be significantly reduced by identifying the risks and the factors influencing these risks through quantified risk assessment where the effect of preventing and mitigation measures can be directly evaluated and compared. This is the means that have been introduced in other industries such as nuclear and aerospace and which have proven successful in reducing major accidents. As mentioned, the current offshore safety regime for the U.S. Gulf of Mexico does not require risk assessment and safety cases to be established. IADC has, however, a recommended approach for a safety case for mobile drilling units. DNV believes that such requirements with extensions must be introduced in the future regulation so that all risks are evaluated throughout the lifetime of the offshore drilling and production activities, including design, construction, installation, operations, maintenance, adaptation of new technologies, modifications and decommissioning.

It should be noted that some operators in the US Gulf of Mexico already perform risk assessments due to their own corporate governance and based on experience from other safety regimes in the world. Furthermore, the challenge of handling an unlimited liability for operators can be met through a systematic risk management approach where active prevention and mitigation barriers are monitored and managed throughout the lifetime.

[5] The term barriers is here used interchangeably with controls or safeguards, which are any technical, human or organizational feature interrupting an accident sequence – either stopping it or reducing its likelihood or consequence or both.

7. Shared performance monitoring

DNV believes that performance monitoring of all factors influencing a safe operation should take place throughout the life time of the facility. The monitoring should include the actual risks updated regularly, the condition of the facility, people and organization as well as the condition of all barriers preventing and mitigating accidents. Such performance monitoring would be a continuous assessment of the total integrity of the operation and ensure that, for example, barriers do not deteriorate.

The performance monitoring should be shared – fully or partly – with all parties participating in the operations such as partners and subcontractors in order for all to benefit from the knowledge of the actual condition. Part of the performance monitoring could be reported as online information to authorities and regulators as part of their oversight function.

8. Practical and economic feasibility

After a major accident there can be a tendency to establish a significant amount of new regulation where all elements may not have an equally good balance between investment and benefits to society. It is important that new regulation is practical and economically feasible in addition to ensuring sufficient safety and environmental protection. DNV recommends that the effectiveness of new regulation should be assessed on basis of a risk assessment where the reduction of risks (reduction of expected loss) due to the new or modified regulation is compared with the investment needed to implement the new or modified regulation.

As has been seen with the Deepwater Horizon accident it can be important that equipment from other parts of the world can be brought into the Gulf without any delay when needed. The regulation in the U.S. Gulf of Mexico should therefore be aligned with international regulation for offshore oil and gas exploration, development and production. Specific requirements needed for the local conditions such as risk of hurricanes should be established and met in addition.

9. A step change for major accidents

DNV believes that a step change for major accidents can be achieved, i.e. that the risk can be reduced by a factor of 10 by use of risk management. The oil, gas and process industries have achieved significant improvements over the past 20 years in occupational safety and limited spills or pollution incidents because companies´ safety and environmental management have focused on and measured progress in these areas. However, major accidents in safety, structural failures, explosions and environmental pollution have been more resistant to improvement (e.g. major accidents onshore: Texas City[6] and Longford Australia, and offshore: Piper Alpha and the Montara blowout).

After the Three Mile Island accident, the nuclear industry achieved a step change using better tools, namely formal Probabilistic Risk Analysis, new audit structures from the Institute of Nuclear Power Operations and stricter regulations. The Offshore industry in the UK and in Norway, following two major disasters with more than 100 fatalities each in the 1980's, has also achieved an improvement by using safety cases and quantified risk assessments. Also the aviation sector has been successful in reducing major accidents.

There are important lessons to be learned from these achievements:

- When seeking a step-change, a holistic approach to address technical, procedural, human and organizational and cultural aspects is essential
- A detailed quantified safety and environmental model is necessary to underpin operational decision making to prevent major accidents

[6] Texas City refinery explosion 2005; Longford Australia gas processing facility fire 1998; Piper Alpha North Sea rig explosion and fire 1988, Montara oil well blowout off Northern Territory 2009 – particularly well documented and studied accidents amongst many

10. Balance between risk, control and condition

In the North Sea offshore industry and the commercial nuclear power industry, a detailed risk model is established and, from this model, all hazards are identified and managed to a level commensurate with the risks. In the offshore energy industry, all risks would include at least all safety and environmental risks from topsides infrastructure, subsea arrangements and downhole. This approach has the benefit of being able to reduce risks as they become directly known and the approach therefore provide additional and higher levels of safety and environmental protection.

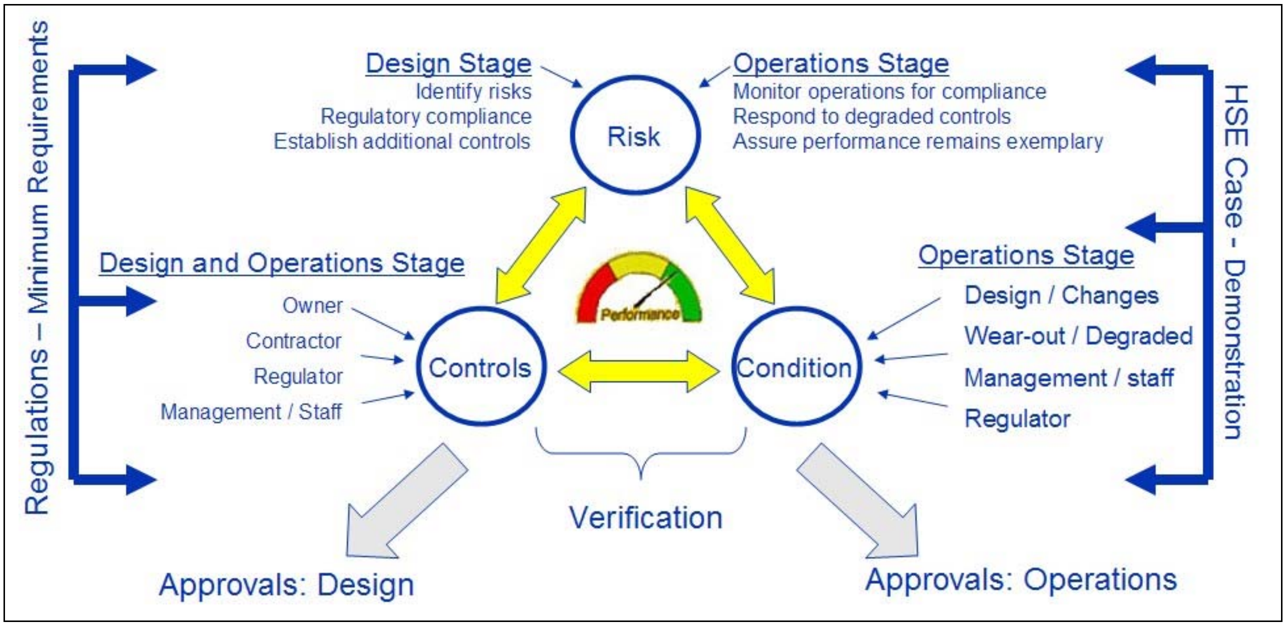


Illustration of the elements Risk, Control and Condition in a risk-informed offshore safety regime

A risk management approach is characterized by three main elements

1. ***Risk: The risk model[7] is the foundation of a safety case***
   - The operator must identify of all risks ranging from high frequency, but small consequences to rare major events with significant consequences, ways and means to prevent these accidents and how to respond if prevention fails. The barrier model – mentioned further in the appendix – is an effective technique to understand prevention and mitigation systems, equipment and operating procedures.
   - The engineering and maritime design must meet current regulations and standards and the safety case must describe the basis for the design and operation.
   - The risk model must have a sound basis and detail. To achieve a step change it must in the design stage be quantified to cover safety and environment risks on the topsides, subsea and downhole. Subsequently, operations procedures may rely on, or require, more qualitative risk models.
   - The risk model is used to establish the required performance of all critical aspects (technical, human and procedural) and these performance standards would be used for verification.

[7] The concepts of a risk model are outlined further in the annex to this paper

2. ***Controls: Effective mechanisms for control must be implemented***

- Ensure that regulatory requirements and safety case commitments are achieved in practice, are documented and communicated to all offshore and onshore staff and contractors
- Ensure that modern safety & environment management system and process safety and safe drilling operations culture programs are in place to institutionalize success and to prevent short term financial Key Performance Indicators from increasing longer term threats
- Verification by an independent, competent party as a key control mechanism both during design and operations

3. ***Condition: The sound condition of all elements must be continuously monitored***

- Complex systems are subject to degradation or failure from the moment of entering service. Processes must be in place to maintain equipment and to ensure that systems meet the required performance standard throughout the life time
- As well as the technical systems may degrade, this is also the case as regards working culture, organization and human competences which must be included in the condition monitoring processes
- Changes in system, organization or people must be assessed, managed, controlled and documented before implementation, with effective processes for returning critical equipment to its current state after temporary changes

It is important to have the right balance between the three elements risk, control and condition. A safety regime which has focus in only one or two of the elements will lead to ineffective risk management. A prescriptive regime focuses typically on control and condition but less on risk.

11. Conclusion

DNV believes that an effective and robust safety regime for offshore energy exploration, development and production must be risk-informed and must possess the following characteristics

- Performance-based supplemented by prescriptive regulation
- Consideration of technology, organization and people
- Clear roles and responsibilities
- Enforced identification, reduction and control of risks
- Shared performance monitoring
- Practical and economic feasibility
- Balance between risk, control and condition

DNV believes that the introduction of a risk management approach as basis for a new regulatory regime within U.S. waters will significantly improve the safety of offshore oil exploration and production. It will meet the public expectations for assessment of all risks as well as accommodate further development in offshore exploration and drilling safety and environmental protection.

DNV believes that it is critical to maintain and use a living quantifiable safety and environmental risk model to support decision making to prevent major accidents. A holistic model is needed that addresses all aspects affecting the safety, such as technical, procedural, human and organizational and cultural aspects.

This paper is intended to introduce the concept of a risk informed approach to safety and environmental regulations, and does not attempt to describe the concept comprehensively. DNV will be pleased to assist and contribute to the discussion and development of an improved offshore safety and environmental regime for the United States.

Appendix

Risk models

A risk model is a formal review of all threats to safety and the environment. Although complex in execution, the basic principles are simple and shown in the figure below. Because of its conceptual simplicity, however, the importance and complexity of asking the critical questions in the analysis of what can go wrong is often underestimated. This analysis needs to be undertaken both from a holistic perspective and from a detailed perspective on technology, people and organization. Therefore, the assessment requires a dedicated and tailor made approach and can not be undertaken by simple checklists or other standardized approaches.

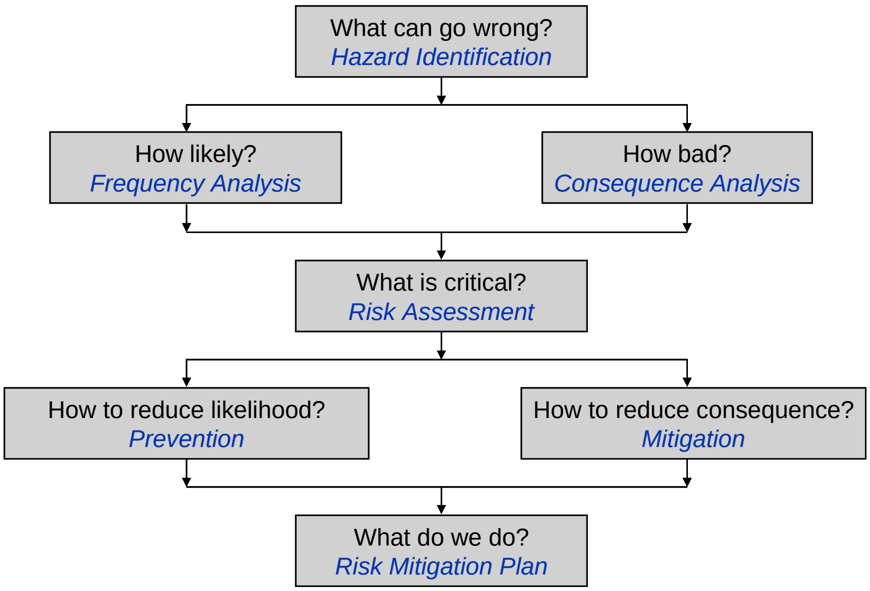


Illustration of the risk assessment and mitigation identification process

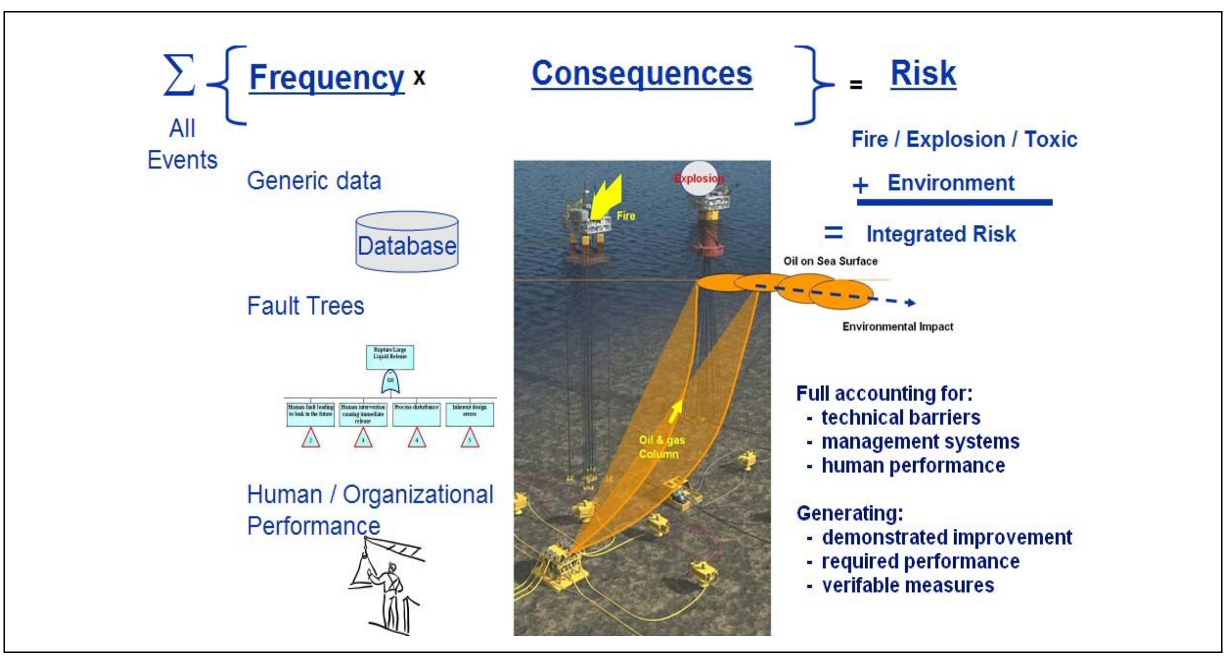


Illustration of a holistic, quantitative risk model for offshore installation

Two risk models should be established, one for the Safety Case during the Planning Stage and one for the Operations Stage as briefly outlined in the following.

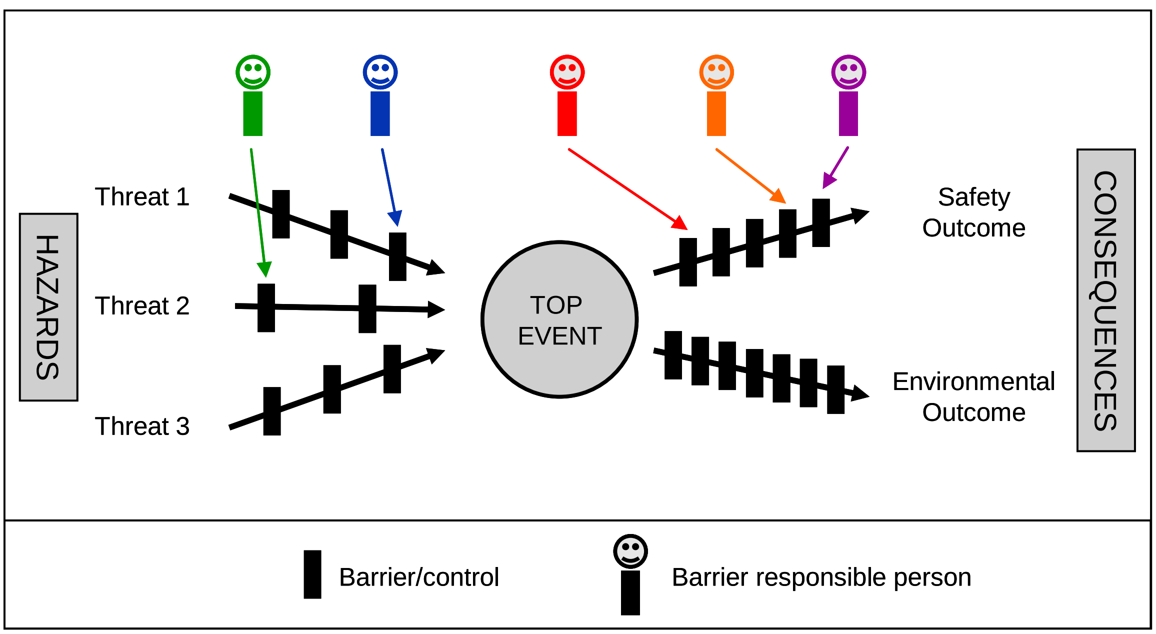
Planning Stage Risk Management

The Planning Stage risk model includes quantified risk assessment (QRA) that uses detailed engineering studies and human performance models to identify all risks and demonstrate how they are prevented and, if an event occurs, mitigated. The figure above illustrates such a holistic, quantitative risk model. Within offshore facilities, there has traditionally been a focus on safety due to fire and explosion on the topside. A holistic model should also include e.g. environment and downhole related risk as illustrated in the figure.

A QRA is a risk model that quantifies key aspects of risk and – importantly – allows for the demonstration of risk reduction by the application of defined safeguards. In many ways, a QRA is similar to a Nuclear Probabilistic Risk Assessment (PRA), except that the numerical approach is a little different (discrete versus probabilistic) and the range of events examined is much broader for the offshore industry while the PRA focuses mostly on the single event of potential reactor meltdown.

Operations Stage Risk Management

The Operations Stage risk model captures all the findings and requirements and translates these into easily understood terms and documents that can be effectively managed and driven into a positive process and safety culture during operations. The documentation will likely consist of a combination of a qualitative barrier diagram approach (often termed a "Bow Tie", see figure below) for foreseen threats and an operational version of the QRA model described in the previous section to address unforeseen issues. The nuclear industry uses also such an operational approach in utilizing the PRA model.



Bow Tie barrier model showing critical barriers (controls).
Prevention barriers are on the left and mitigation barriers on the right.
Each barrier should have a responsible person - only some of these are illustrated.

Most accidents (e.g. Bhopal, Texas City) have been demonstrated to be due not to an unforeseen threat, but due to a known threat adequately addressed by regulations and company requirements, but where the safeguards have been allowed to degrade over time (technical, human or organizational). The Chemical Safety Board investigations have shown the same to be true in other serious U.S. accidents (e.g., recent explosion at Imperial Sugar, Georgia).

Thus, a vital output of the Operations Stage risk model is that it be maintained up-to-date to provide a clear understanding of the current status of all barriers and how they affect risks, when these have degraded what must be done to return the system to a safe state, and ensure that all company staff, contractors and regulators are aware of the barrier status at all times in daily operations.

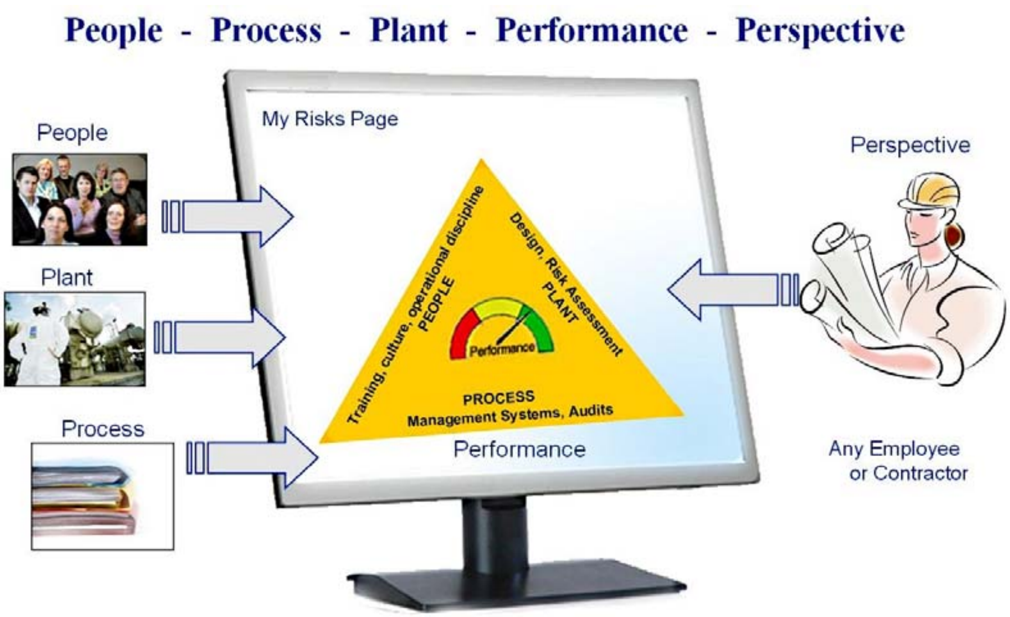
Verification and improvements through audits, reviews and inspections

Regular audits during operations of the risk management system are vital. Important areas that need to be addressed are the management system, the process safety and organizational culture, seamless processes across company staff, contractors and sub-contractors, offshore and onshore as well as the status of all barriers. Also the readiness of prevention barriers must be included, such as emergency and mitigation measures e.g. for containment of oil flow from a well and reduction of oil spill in the ocean.

Management and staff reviews must in the same way be executed regularly in order to improve continuously. Finally, regular and in-depth technical inspection and verification of physical facilities are needed to ensure robust integrity.

Effective communication and decision making

Modern information and communication technology can be an effective support in sharing performance monitoring of risks and barriers as well as for making team-based decisions for critical situations in an integrated operations environment as illustrated in the figures below.



IT system can be used to communicate the current status on barriers and risk to allow everyone anywhere to access this information in real-time

Conference systems allow for “Decision Rooms” where offshore and onshore staff, contractors and regulators can meet in a common place for superior team-based decisions

About DNV

With the corporate objective of safeguarding life, property and the environment, DNV helps business and society to manage risks on basis of DNV´s independence and integrity. DNV serves a range of industries with special focus on the energy and maritime sectors.

Established in 1864, DNV has a global presence with a network of 300 offices in 100 countries, and is headquartered in Oslo, Norway. As a knowledge-based company, DNV’s prime assets are the creativity, knowledge and expertise of our 9,000 employees.

DNV is a global provider of services for managing risk, helping customers to safely and responsibly improve their business performance. As companies today are operating in an increasingly complex and demanding risk environment, DNV’s core competence is to identify, assess and advise on how to effectively manage risk, and to identify improvement opportunities. Our technology expertise and deep industry knowledge, combined with our risk management approach, have been used to manage the risks in high-profile projects around the world.

DNV in USA

DNV opened its first office in USA in New York in 1898. Today DNV has 700 employees in USA with offices in Atlanta, Chicago, Columbus, Cincinnati, Detroit, Houston, Jacksonville, Long Beach, Boston, Miami, Norfolk, New Orleans, New York, Portland, Seattle, San Francisco and La Porte.

DNV’s main activities in USA are within the energy sector, both within oil & gas exploration, development and production as well as within wind energy. DNV is engaged in verification, classification and asset risk management offshore in the Gulf of Mexico and within risk management of onshore pipelines and refining. DNV has a Deepwater Technology Center in Houston and a leading Corrosion and Materials Technology Center in Ohio focusing on management of degradable structures. The Technology Center in Ohio was a leader in the development of pipeline corrosion assessment standards referenced by US Federal Regulations. DNV is the largest independent consultancy within wind energy in USA.

DNV helps the maritime industry to manage risk in all phases of a ship’s life through ship classification, statutory certification, fuel testing and a range of technical, business risk and competency-related services. DNV is among the top two classification societies for mobile offshore units. DNV is present in all maritime clusters in U.S. and our Global Cruise Center located in Miami supports our leading position in this sector.

DNV and Authorities

DNV works for and on behalf of more than 130 authorities as an authorized, notified or accredited body within classification of offshore structures and ships, within certification of management systems and products and within validation and verification of climate change projects on behalf of United Nations.

DNV is authorized by the US Coast Guard as a classification society, approved by Department of Interior as a Certified Verification Agent, accredited by ANSI-AQS National Accreditation Board for certification services and approved by US Centers for Medicare and Medicaid Services to accredit hospitals.

DNV Offshore Codes

The DNV Offshore Codes are a comprehensive set of documents in a 3-level hierarchy consisting of Offshore Service Specifications, Offshore Standards and Recommended Practices. The DNV Offshore Codes are referenced in a number of offshore safety regulations.

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