Risk Based Decision Making – a Necessary Approach for Reducing the Risk of Oil Spills along the Norwegian Coast

Stein Motrøen, Consultant, Maritime Solutions, DNV, NO-1322 Høvik
Benedikte H.Wentworth, Senior Consultant, Maritime Solutions, DNV, NO-1322 Høvik

Today, decision makers are facing a new and more challenging risk reality. Society is gradually adopting a "zero tolerance" for failure, stakeholders are constantly suggesting new and isolated risk reducing measures, and the increasing attention from media and the public makes it difficult for authorities and politicians to make well considered decisions. Due to requirements from authorities, and generally high focus over a period of time, risk management methods are used to a large extent in the Norwegian offshore activity. Related to the shipping activity risk management is used on a more individual basis. To ensure that the best combination of risk reducing measures are implemented and that the risks related to oil spills along the Norwegian coast is as low as reasonably practical, there is a need for a more holistic risk management approach.
Risk management is a systematic and proactive approach which ensures that resources are used in the most optimal manner. To effectively implement this along the Norwegian coast coordination is needed to ensure the best combination of measures across geographical boarders and disciplines. The approach leads to a common understanding of the following issues:

- *Current and future risk levels*
- *Risk acceptance criteria*
- *Frequency and consequences of various types of accidents*
- *Cost and benefit of various types of risk reducing measures*
- *Prioritisation and implementation of risk reducing measures*

Risk management results in a structured methodology for evaluating the cost-effectiveness of the different risk reducing measures. By implementing the best combination of risk reducing measures, the risk is controlled in an optimal socio-economic manner and the decisions are transparent and hence easy to communicate.

Introduction

Today, the shipping activities along the Norwegian coast undergo an increased focus and attention from the public and the media. The fear of experiencing a devastating oil spill is obvious, and there are continuously raised new and isolated proposals with respect to risk reducing measures. This situation makes it difficult for authorities and politicians to make well considered decisions. This situation creates a need for a decision basis that is holistic, structured and well documented.

The decision basis should provide answers to at least five important questions:

1. What levels of risk are we willing to accept?
2. How large is the risk associated with the oil transport?
3. What types of accidents happens most frequently and which have the largest consequences?
4. Which risk reducing measures are available and which are most cost effective to implement?
5. Which measures should be prioritized and how should they be implemented most effectively and efficiently?

Risk Management

Risk management may be defined as the process of identifying, analysing, evaluating and controlling risks. Risk management is not only a tool, it is a continuous *process*. The motivation factors for utilising risk management are:

- It enables the demonstration of a pro-active approach. In an increasingly dynamic and changing world, a pro-active approach is necessary to succeed.
- It ensures that risk is systematically handled and managed.
- It ensures a transparent and result oriented decision process, where decisions are justified based on socio-economic arguments.
- Quantitative risk assessment and cost-benefit assessments enable easy buy-in and justification of investments.

Throughout its 140-year history, DNV has, through ship classification, contributed to risk management. However, systematic risk management goes far beyond classification and minimum requirements. DNV has followed the international trend and focused on safety, quality and reliability the last decades. Today, DNV also provides risk management services that go beyond compliance. Some areas where DNV differs from most other players in the maritime industry are:

- DNV has long tradition within maritime consultancy, delivering services beyond classification, tailored to the need of each client
- DNV has extensive experience with risk analyses and risk assessments within the maritime industry
- DNV has the last few years introduced Formal Safety Assessment (FSA) in its rule development process, and in that connection developed generic risk assessments of all major ship types and segments

Through the introduction of FSA in the rule development process, DNV has developed generic risk assessment of all major ship types, with special emphasis on the risk for oil tankers. These risk assessments (denoted risk pictures) present the historical risk for the vessel types in terms of:

- Personnel risk
- Environmental risk
- Property damage risk

The most important contributors to these risks are identified, both in terms of accident type (collision, fire/explosion, grounding, etc.) and cost drivers (clean-up costs, repair costs, etc.). The risk pictures include smaller events, such as auxiliary engine breakdown, as well as catastrophic events, such as grounding with subsequent total loss of vessel and oil spill clean-up and compensation costs. The latter type of events has a minor frequency, but the risk could be significant, as the costs are great.

Risk Management along the Norwegian Coast

There are two main sources for critical oil spill along the Norwegian coast: the offshore and shipping activity. Due to requirements from authorities, and generally high focus over a period of time, risk management methods are used to a large extent in the Norwegian offshore activity. Related to the shipping activity risk management is used on a more individual basis. To ensure that the best combination of risk reducing measures are implemented and that the risks related to oil spills along the Norwegian coast is as low as reasonably practical, there is a need for a more holistic risk management approach.

Risk management is a systematic and proactive approach which ensures that resources are used in the most optimal manner. To effectively implement this along the Norwegian coast coordination is needed to ensure the best combination of measures across geographical boarders and disciplines.
The generic risk management process is used independent of type of industry, organisational level or complexity. However, the process implementation and execution of each step are adapted to the characteristics and requirements of a specific organisation or application. The DNV process, which is illustrated in Fig.1, consists of the following five steps:

1. Initiation and focus
2. Hazard Identification(HAZID)
3. Risk assessment
4. Cost-Benefit assessment
5. Implementation of measures

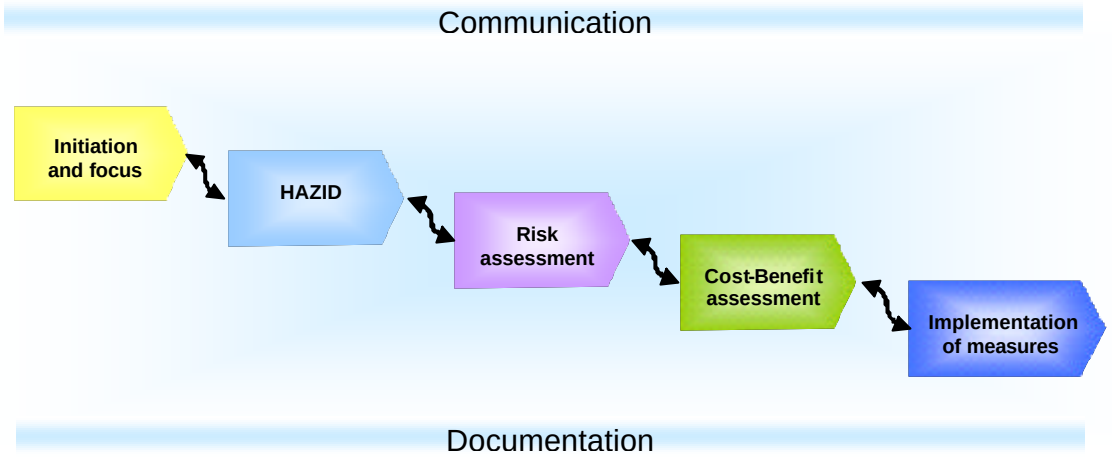

Fig.1 Risk management process

Step 1 - Initiation and Focusing

In order to get the process started and focused in the right direction, it is necessary to carry out a pre-structuring. In this phase, the basis for the project and process is established. The objective is to establish a motivated project team, understand the issues, establish the knowledge base, and develop a good problem solving approach.

The step should result in well defined objectives for the project and process, scope and limitations, as well as a framework. Tools and techniques should be selected, as well as problem solving approach. In this phase, it is necessary to evaluate existing policies, strategies, procedures, requirements, etc.

In addition, it is important to focus on the approach related to the risk assessment. That is, the stakeholders should be involved in the process to decide on risk categories and to establish measurements for frequencies and consequences. In order to enable this process, the existing level of risk should be established as far as this is possible. That is, brief statistical searches should be carried out (e.g. based on data available for world-wide

operations) in order to estimate historic risk levels. In cases where risk models exist, these should be included.

Risk acceptance should also be discussed and agreed upon. In the past, terms such as "acceptable level of safety and reliability" have in effect been defined by subjective judgement, incrementally modified in response to accident experience. It is important that greater transparency is achieved by the use of numerical acceptance criteria. Acceptance criteria are typically of the following two types [Andreassen et al, 2004]:

- Risk acceptance criteria that define the boundaries between three zones – in effect the limits of the As Low As Reasonable Practicable (ALARP) region within which costs and benefits of risk reduction are considered.
- Cost-effectiveness criteria to define when risk reduction is "reasonably practicable" for risks within the ALARP region.

The different regions, i.e. acceptable risk, ALARP and unacceptable risk region, are illustrated in Fig.2

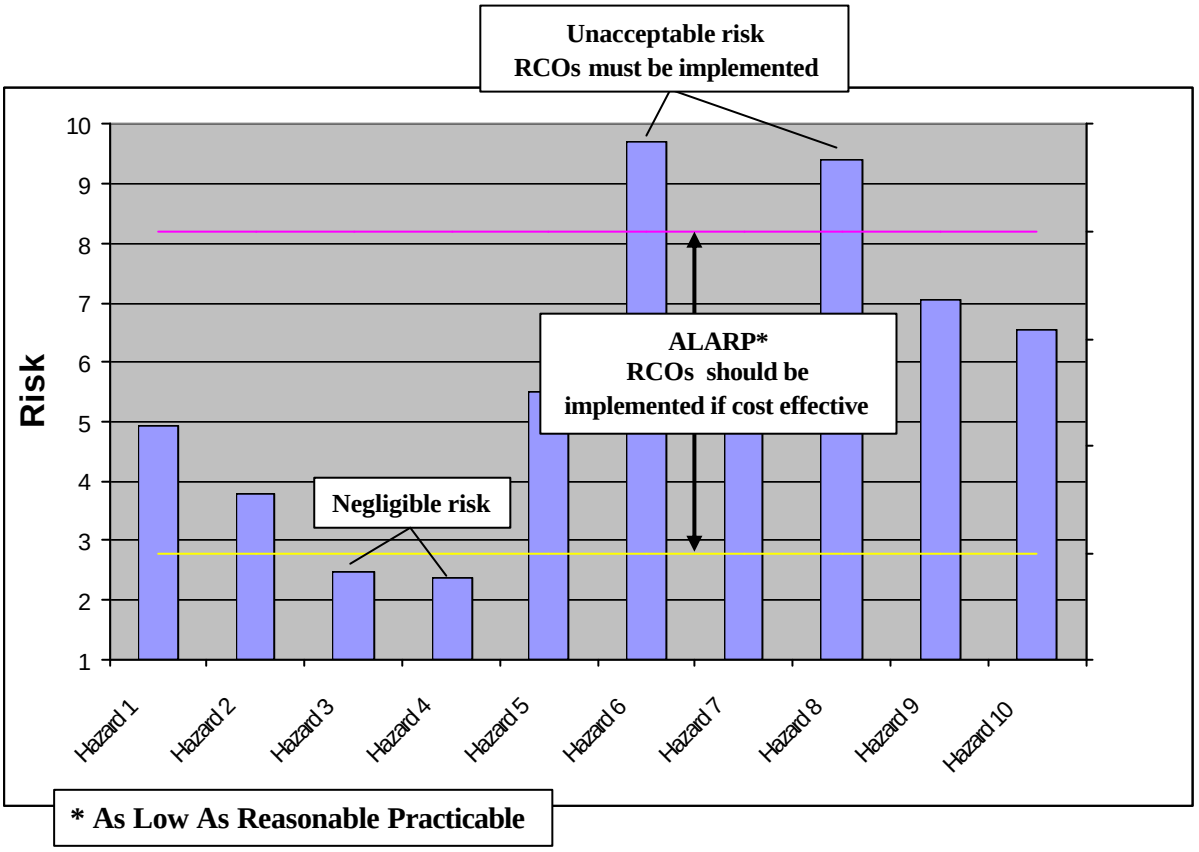

Fig.2 Different risk acceptance regions

Finally, a plan (with milestones and responsible persons) for the risk management process should be established and agreed upon.

Step 2 – HAZID

A HAZID (HAZard IDentification) is a structured brainstorming session that answers the following questions:

1. What might go wrong?
2. Why does it go wrong?
3. What are the consequences of it going wrong?
4. How may it be avoided?

That is, the HAZID results in identification of hazards, causes and consequences, and possible risk control options (RCOs). This scope is a bit extended from the traditional way of defining HAZID. Based on DNV experience it is very valuable to include question 3. and 4. as early as possible and preferably together with the identification of hazards. It is based on experience and expert judgement, and it is obtained through structured workshops and brainstorming sessions. In addition, some issues may be based on questionnaires and interviews. The documentation of the HAZID results in a risk register. The risk register represents input both to the risk assessment (Step 3) and the identification and selection of RCOs (Step 4).

Step 3 - Risk Assessment

In order to be focused on the high risk areas and to identify and evaluate the factors that influence the level of risk, it is necessary to identify the distribution of risk. The different types of risks, such as risk to people, environment and property, should be addressed as appropriate related to the problem under consideration. In DNV, the following types of risks are typically addressed [Andreassen et al, 2004]:

- Individual fatality risk per person year
- Societal fatality risk per ship year
- Risk of serious casualties
- Risk of total loss of ship per ship year
- Risk of oil spill

A large number of methods for risk assessments exist. Common to most methods are the estimation of risk exposure as the Frequency of an unwanted occurrence times the consequence of the occurrence:

$$\text{Risk} = \text{Frequency} \times \text{Consequence}$$

and the establishment of models for frequency and consequence. That is, in general, risk assessment may be divided into estimation of frequencies and consequences. Frequencies are the probability that an accident occurs per year, and the associated model focus on possible reasons for the accident to occur. Different accidents may have different consequences, and the associated models represent the chain of events following the accidents.

The risk models are established based on statistical, historic data (a large number of databases exist), experience and expert judgement. Expert judgments are typically obtained through structured workshops and interviews. Often, risk matrices, as illustrated in Fig.3, are valuable when discussing risks. In a risk matrix, different risks are categorised and presented based on their probability and consequence. It is absolutely necessary that assumptions made are clearly stated, that expert judgments are based on observable

quantities and that the approach is well documented [Andreassen et al, 2004]. It is important that risk reducing measures that are already implemented (e.g. AIS) and risk reducing measures that are soon to be implemented are taken into account (e.g. VTS in Finnmark). Special care should be taken when including combined effects of several similar RCOs.

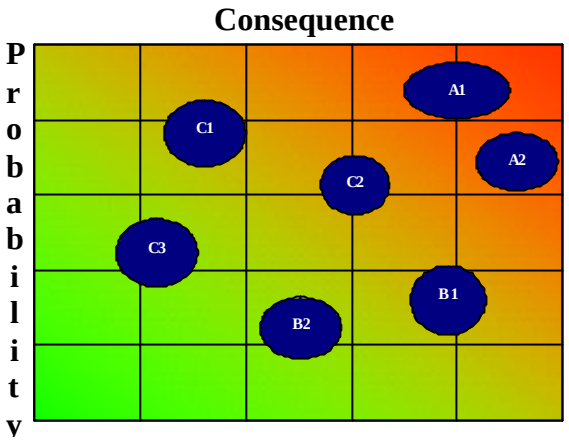

Fig.3 Risk matrix (Green area = Negligible risk, Yellow area = ALARP area and Read area = Unacceptable risk)

The risk assessment may be presented as a risk matrix, as already shown in Fig.3, or as risk pictures, as illustrated in Fig.4 and Fig.5.

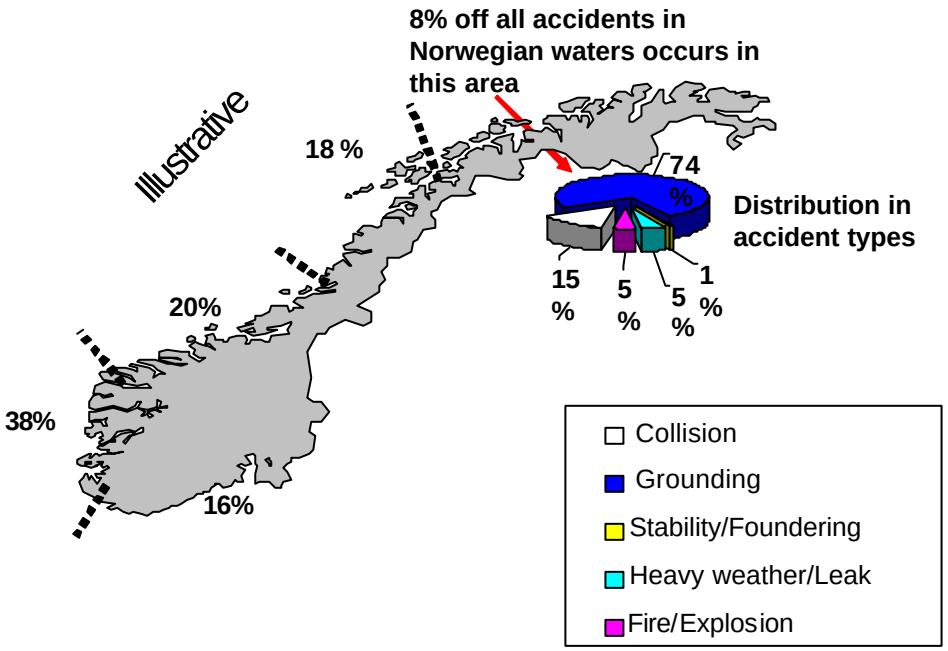

Fig.4 Risk picture based on statistics

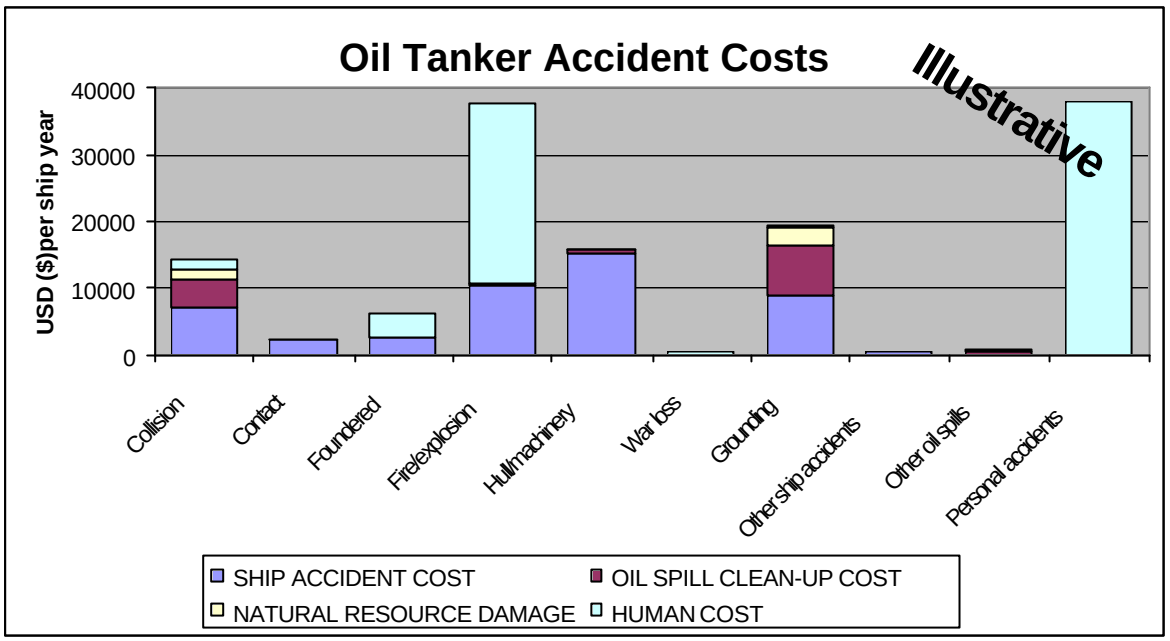

Fig.5 Risk picture – oil tanker accident costs

The results from the risk assessment are:

- Base risk levels (i.e. current risk levels)
- Identification of high risk areas needing to be addresses
- Models to be used in the evaluation of benefits associated with the different RCOs.

The risk assessment enables the identification of critical risk factors, rating of the risk factors, and a well structured method of documenting the distribution of risk.

When evaluating the consequences of an accident with spill along a coastline, it is also necessary to consider the sensitivity of the area under consideration, see Fig.6. In addition, it may be appropriate to evaluate consequences in the terms of losses related to tourism, decreased property values, etc.

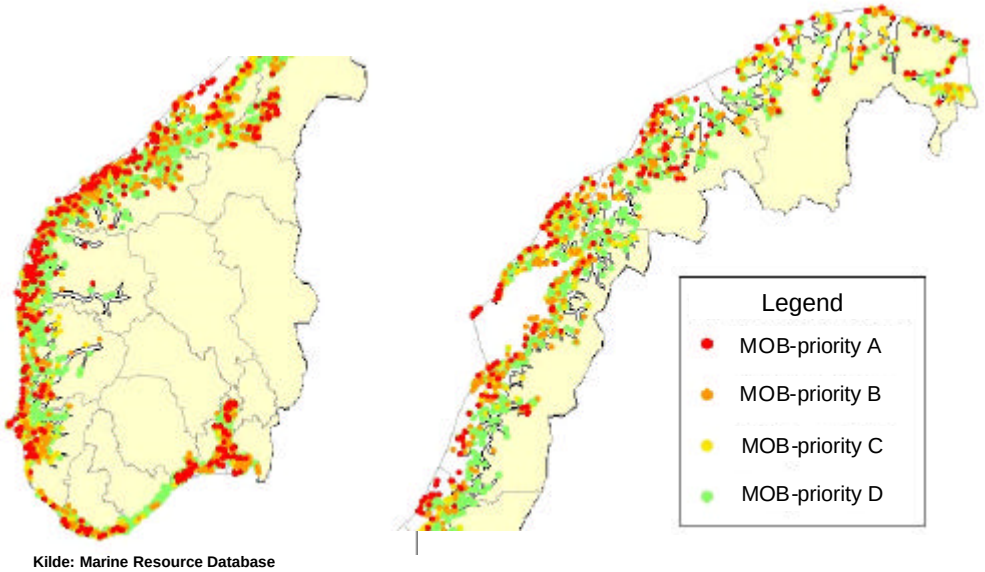

Fig.6 Natural resources prioritised based on conservational value, vulnerability to oil pollution, natural occurrence and potential for economical compensation

Step 4 - Cost-Benefit Assessment of Risk Control Options

In order to prioritise among different RCOs, it is necessary to evaluate the cost and benefit of the different measures. Different RCOs are typically identified in the HAZID (Step 2) session. In addition, it is likely that additional RCOs are identified during the risk assessment (Step 3).
When it comes to RCOs related to managing spill risk related to transportation of oil along the Norwegian coast, it may be categorised as in Fig.7. As seen from the figure, some RCOs primarily reduce the frequencies of accidents, while others primarily reduce consequences. Similarly, some RCOs are valid for the vessels sailing along the coast, while others are related to the infrastructure along the coast. Along the Norwegian coast, the Norwegian Maritime Directorate is the authority that has the largest influence on RCOs related to the vessels, while the Norwegian Coastal Administration and the Department of Fisheries are the authorities that have the largest influence on RCOs related to the infrastructure.

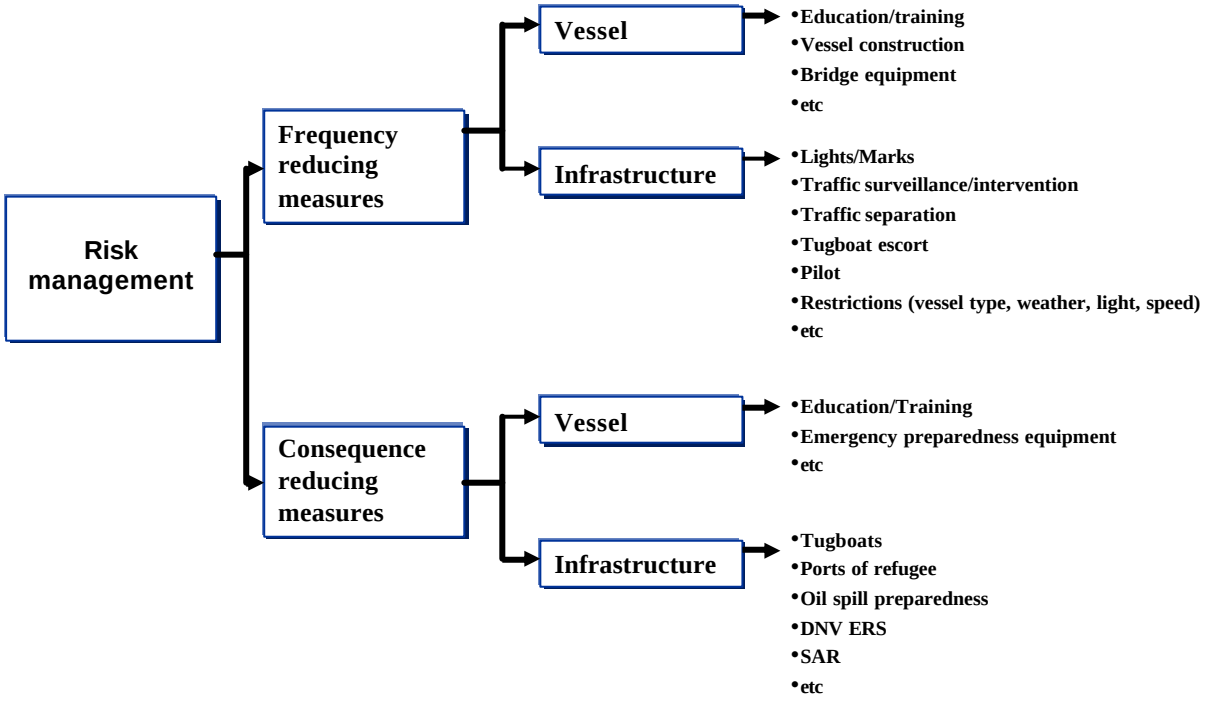

Fig.7 Categorisation of RCOs

The risk control options identified in the HAZID (Step 2) are typically also prioritized in this session. Similarly, the risk assessment (Step 3) contributes to a prioritisation of the RCOs by identifying high risk areas. Generally, the RCOs should aim at one or more of the following [Andreassen et al, 2004]:

- Reducing the frequencies of failures through better design, procedures, policies, training, etc.
- Mitigating the effect of failures in order to prevent accidents
- Alleviating the circumstances in which failures may occur
- Mitigating the consequences of accidents

That is, when selecting RCOs for further evaluation, preventive options should have priority before mitigating options, design options should be preferred before operative options, and passive systems should have higher priority than active systems.

The cost assessments of the selected RCOs typically include investment and operational costs, including training of personnel and maintenance of equipment. It should be expressed in terms of lifecycle costs. The benefit assessments of the RCOs results from calculating the savings based on reductions in risk. That is, it may include reductions in costs associated with injuries, fatalities, casualties, environmental damage and clean-up, third party liabilities, etc. Typically, the benefit is found by utilising expert judgement together with the risk models established in Step 2, to predict the specific RCOs effect on the risk picture. Based on the cost-benefit assessment, the RCOs are prioritised.

In addition, to get an overview of the total costs and benefits of the different RCOs, the cost-benefit assessment should provide information regarding which stakeholders and entities that carry the costs and experiences the greatest benefit.

Following the cost-benefit prioritisation, the RCOs must be evaluated with respect to how well suited they are for implementation, political implications, etc.

Step 5 – Implementation of Measures

Based on the evaluations carried out in Step 4, the best RCOs have been selected. The next step, which is just as critical, is the implementation of the selected measures. It is absolutely necessary that all parties involved together establish and agree on an implementation plan, including milestones and clearly defined responsibilities. Following successful implementation, evaluations of the implemented RCOs must be performed.
Given today's climate of rapid change, rough competition and tight resources, surveillance of the risks and the implemented RCOs must continuously be carried out, in order to be pro-active with respect to changes. This final stage of the risk-based decision making process is thus to continually repeat the process (or portions thereof). This is done in order to ensure that the decision made remains the optimal one given the changes to the system that inevitably take place.

Application of method

DNV has extensive experience in the application of the method presented above. The following sections introduces an example of how the method can be applied to evaluate the risk for crude oil spill from tankers in a defined area and the effect of introducing risk reducing measures related to the ship traffic in the area. The example will answer the basic questions introduced:

1. What levels of risk are we willing to accept?
2. How large is the risk associated with the oil transport?
3. What types of accidents happens most frequently and which have the largest consequences?
4. Which risk reducing measures are available and which are most cost effective to implement?
5. Which measures should be prioritized and how should they be implemented most effectively and efficiently?

The project example follows the five steps introduced in the method:

Example Step 1 – Initiation and Focusing

In order to get started and focus in the right direction Step 1 should result in well defined objectives for the project and process, scope and limitations, as well as framework. The project group should be established, and risk acceptance criteria should be discussed and agreed upon.

Question 1: What levels of risk are we willing to accept?

The first step of the risk management process is to agree on the risk acceptance criteria:

- Based on the proposed petroleum production in the defined area the client will not accept more than 200 tonnes of crude oil in the ocean per year (**annual average**).
- Below this limit of unacceptable risk, ALARP (As Low As Reasonable Practical) should be demonstrated (meaning that all measures that have a positive net benefit should be implemented)

Example Step 2 – Hazard Identification (HAZID)

To conduct the HAZID a group of experts and/or people with experience from the area in question should be gathered. The brainstorming session should work through the details of the operation and identify the hazards involved in the operation.

Question 3: What types of accidents happens most frequently?

Based on a HAZID the most significant hazards believed to cause crude oil spill in the defined area in connection with petroleum production are identified:

- Powered Grounding
- Drift Grounding
- Collision
- Structural Failure
- Fire/Explosion

Question 4: Which risk reducing measures are available?

The HAZID also identifies the most significant risk control options:

- Redundant Propulsion
- Escort Tug
- Towboat Assistance

Example Step 3 – Risk Assessment

Question 2: How large is the risk associated with the oil transport?

Based on a thorough risk assessment, the overall risk is estimated as 292 tonnes crude oil in the ocean per year (see table below).

Question 3: What types of accident happens most frequently and which have the largest consequence?

The risk assessment gives the following distribution of the hazards based on estimated tonnes of crude oil spilled per year:

1. Drift grounding (40 %)
2. Collision (20 %)
3. Structural failure (18 %)
4. Powered grounding (12 %)
5. Fire/Explosion (10 %)

The table below illustrates the calculation of which accident will happen most frequently, which have the largest consequence and the total risk associated with the oil transport:

Accident Identification	**Return Period** *[years/accident]*	**Average oil spill per accident** *[tonnes/accident]*	**Average oil spill per year** *[tonnes/year]*
Powered Grounding	1 348	45 787	34
Drift Grounding	463	45 979	99
Collision	406	37 111	91
Structural Failure	2 999	76 930	26
Fire/Explosion	266	11 230	42
Total/Average	106	30 948	292

Example Step 4 – Cost-Benefit assessment of risk control options

Question 4: Which risk reducing measures are most cost effective to implement?

The benefit for each RCO identified is calculated and the result for all hazards is shown below (NB! These figures should not be used for generic purposes. In other areas, with different activity, the outcome of the analysis could be the opposite):

1. Escort tug, benefits significantly higher than cost of implementation
2. Tugboat assistance, benefits equal to cost of implementation
3. Redundant propulsion, benefit significantly lower than cost of implementation

The tables below illustrate the calculations:

Calculate the cost and the benefit for each RCO identified:

Risk Reducing Meassure	**Cost of meassure** *[NOK/year]*	**Benefit of meassure** *[NOK/year]*	**Net benefit of meassure** *[NOK/year]*	**Cost/Benefit ratio** *[-]*
Redundant Propulsion	825 600 000	11 326 600	-814 273 400	0,014
Escort Tug	5 070 000	11 801 200	6 731 200	2,328
Enhanced Bridge Equipment	49 920 000	2 911 600	-47 008 400	0,058
Tugboat Assistance	4 510 000	4 670 100	160 100	1,035

Prioritising of risk reducing measures:

Rank	Risk Reducing Meassure	Cost/Benefit ratio *[-]*	Oil spill reduction *[tonnes/year]*	Cost for reducing crude oil spill *[NOK/tonnes]*
1	Escort Tug	2,33	107	47 514
2	Tugboat Assistance	1,04	40	113 499
3	Enhanced Bridge Equipment	0,06	39	1 289 372
4	Redundant Propulsion	0,01	214	3 850 064

Example Step 5 – Implementation of measures

Question 5: Which measures should be prioritized and how should they be implemented most effectively and efficiently?

Based on the cost effectiveness of the RCOs, only escort tugs should be implemented for the defined area. After implementation of the cost effective RCOs, the estimated annual spills of crude oil is reduced. Hence, the net benefit for the next measure should be calculated using the new, reduced risk level.

Following the cost-benefit prioritisation, the RCOs must be evaluated with respect to how well suited they are for implementation, political implications, etc.

Conclusions

As seen from the above discussion, implemented RCOs are selected based on a structured, transparent and easily communicated approach. That is, the process results in well considered recommendations which are easily communicated and easy to understand. Risk management represents a structured process for evaluating different options and by implementing the best combination of RCOs, the risk is controlled in the best possible manner and the decisions are transparent and easy to communicate.

References

Book: Andreassen E., Kjellström S. and Wentworth B. (2004) Rule development based on Formal Safety Assessment