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Perspectives on Risk Acceptance Criteria and Management for Offshore Applications – Application to A Development Project

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Abstract

Risk acceptance criteria as upper limits of acceptable risks have been used for offshore activities on the Norwegian Continental Shelf for more than 20 years. The common thinking has been that risk analyses and assessments cannot be conducted in a meaningful way without the use of such criteria. We challenge this thinking. A case studied is presented that demonstrates how the risk management process can be defined and implemented for an offshore development project, without such criteria. Focus is on risk reduction processes emphasising generation of alternatives, cost-effectiveness and management involvement in the decision-making process.

Keywords: Risk acceptance criteria, ALARP, Cost-effectiveness

1. Introduction

Risk acceptance criteria as upper limits of acceptable risks have been used for offshore activities on the Norwegian Continental Shelf for more than 20 years. The ALARP principle also applies, but the risk acceptance criteria have played a more active role in the assessment processes than seen for example in the UK.

Formally speaking, it may be argued that the Norwegian legislation has the required encouragement for further risk reduction. There is in the regulations a requirement for an ALARP evaluation of risk, in addition to the use of risk acceptance criteria. Unfortunately, this is more a formality rather than reality. In practice, the ALARP evaluation is usually also carried out in a mechanistic manner. Very often, this process implies that possible improvements are identified, but immediately disregarded, based on a narrow minded cost/benefit (cost/effectiveness) analysis. This analysis is often perfunctory, or very coarse.

Satisfying upper limit risk criteria is from a decision making point of view a different approach compared to an ALARP evaluation. Satisfying upper limit risk criteria is a kind of a binary

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decision making, e.g. is this an acceptable technical solution or not? An ALARP evaluation represents a more complex decision making situation, requiring more involvement from managers and technical/professional disciplines in order to find an optimum solution, taking economical, time and safety issues and constraints into consideration.

In this paper we summarise the main points of the above discussion. We argue that the use of such criteria is not consistent with an efficient risk management strategy and should be replaced by a risk analysis regime emphasizing generation of alternatives, cost-effectiveness and management involvement in the decision-making process. This means a closer resemblance with the ALARP principle as adopted in the UK and other countries, but is not a direct application of this practice. Also the building blocks of the common way of applying the ALARP principle are reviewed.

A case studied is presented that demonstrates how the risk management process can be defined and implemented for an offshore development project. The case study covers the planning phases of project on the Norwegian Continental Shelf. Through the case study we demonstrate how risk reduction processes can be carried out emphasising generation of alternatives, cost-effectiveness and management involvement in the decision-making process.

For reviews on how the use of risk acceptance criteria have been used in the Norwegian offshore oil and gas industry, see [1, 3, 7, 12, 22, 23]. The ALARP principle is discussed in these references as well as in [10, 15, 17, 20]. For additional references covering risk acceptance and risk acceptance criteria we refer to [2, 5, 6, 9, 16, 18, 19, 21].

2. The Present Risk Analysis Regime on the Norwegian Continental Shelf

The Norwegian safety regime reflects the basic principle of the licensees' full responsibility for ensuring that the petroleum activity is carried out in compliance with the conditions laid down in the legislation. The safety regime has since 1985 been founded on internal control, meaning that the authorities' supervisory activities are aimed at ensuring that the management systems of the licensees are catering adequately for the safety and working environment aspects in their activities.

The NPD (Norwegian Petroleum Directorate) regulatory guidelines for concept safety evaluation (CSE) studies were introduced in 1980. The guidelines introduced a quantified cut-off criterion related to the impairment frequency of stated main safety functions for nine types of accidents that could be disregarded in further evaluation processes, the so-called 10^{-4} criterion, i.e. a maximum frequency of 10^{-4} per year for each accident type. These guidelines contributed in a positive manner to using formalised techniques for analysis of risk in the industry, and encouraged the industry and authorities to communicate regarding risk and acceptable risk. However it also had some unfortunate effects, as it could seem that 'number crunching' exercises could divert attention from concentrating on the real issues. Too much emphasis was placed on the methodology and the 'magic' 10^{-4} target.

New NPD regulations regarding implementation and use of risk analyses came into force in 1990, and new regulation on emergency preparedness appeared in 1992.

The 1990 regulation had a focus on the risk analysis process. The purpose of the risk analyses is to provide a basis for making decisions with respect to choice of solutions and risk reducing measures. According to the regulations the operator shall define safety objectives and risk acceptance criteria. The objectives express an ideal safety level. Thereby they ensure that the planning, maintaining and the further enhancement of safety in the activities become a dynamic and forward-looking process. Accidental events must be avoided (any actual accidental event is unacceptable). This means that risk is kept as low as reasonably practicable (ALARP), and attempts are made to achieve reduction of risk over time, e.g. in view of technological development and experience. The need for risk reducing measures is assessed with reference to the acceptance criteria. The acceptance criteria and the basis for deciding them are to be documented and auditable.

New NPD Regulations relating to management in the petroleum activities came into force from 1.1.2002, [12-13]. In these regulations the ALARP principle is one of the fundamental principles the regulations base themselves on. The regulations in addition state that the operator shall formulate acceptance criteria relating to major accidents and to the environment. The acceptance criteria shall be used for evaluation of results from the various QRAs and shall be given for

a) personnel on the installation as a whole, and for personnel groups that are particularly exposed to risk
b) loss of main safety functions
c) pollution from installation.

In order to fulfil the requirements and acceptance criteria for major accidents the NORSOK Z-013 standard is recommended, [11].

Some examples of typical risk acceptance criteria used, are

- The FAR value should be less than 10 for all personnel on the installation, where the FAR value is defined as the expected number of fatalities per 100 million exposed hours
- The individual probability that a person is killed in an accident during one year should not exceed 0.1%.

The main characteristic of the present Norwegian system is a relatively 'mechanistic' approach to risk analysis and evaluation, implying that the focus is often limited to satisfying the risk acceptance limits, usually with no or small margin.

The result is that there is no or little encouragement for the operating companies to consider if further risk reduction is possible or achievable. When there is little or no margin in an early phase of a development project, this implies that later design changes may result in risk increase and exceeding the acceptance limits, often with contractual difficulties between the design contractor and the operating company for the installation in question.

In a mechanistic system based on risk acceptance limits, the operator needs to demonstrate to the authorities that the limits have been met, this is often achieved by referencing the risk results, and the authority involvement is sometimes rather superficial.

With an ALARP approach, this also implies that the authority involvement needs to be stronger. The ALARP demonstration is more comprehensive than just simply inspecting risk results. For authorities to review an ALARP demonstration, an extensive evaluation process will normally be needed, in order to determine if a sufficiently wide search for alternatives (e.g. possible risk reducing measures) was taken, and whether arguments relating to gross disproportion are valid. The consequence will be that authorities will need more effort.

In the design process of installations the concept safety evaluations are still actively used, with cut-off criteria of the form 10^{-4} per year to establish the design accidental loads.

The regulations from 1990 and 2002 have also focused on the performance of the safety barriers, and there is an ongoing process of establishing appropriate performance requirements to these barriers. Performance can be expressed by measures such as reliability, effectiveness, capacity and robustness (antonym vulnerability). This process is linked to the implementation of several standards, such as the standard IEC 61511 on Safety Integrity Level (SIL), which introduces a categorization scheme for safety system reliability requirements, [8, 14].

3. Our Perspective on Risk Management

Our starting point is a decision situation where a decision maker is to choose among a set of decision alternatives relating to whether or not to execute an activity, the choice of concepts, design configurations, risk reducing measures, etc. The situations are characterized by a potential of rather large consequences and large associated uncertainties of what will be the consequences, if the alternatives are in fact being realized. The consequences and associated uncertainties relate to economic performance and possible accidents leading to loss of lives and/or environmental damage, possibly also extensive damage to assets and production delay loss. Risk analyses, sensibly conducted, are considered to give valuable decision support in such situations, and

according to the present risk analysis regime in Norway, risk acceptance criteria should be used together with the results from these analyses as input to risk evaluation. In this section, however, we will present and discuss a thinking where such criteria are not being adopted at all.
The main building blocks are described through the following procedure;

1. Perform a crude analysis of the benefits and burdens of the various alternatives addressing attributes related to feasibility, conformance with good practice, economy, strategy considerations, safety related risk, social responsibility, etc. The analysis would typically be qualitative and its conclusions summarized in a matrix with performance shown by a simple categorization system such as Very positive, Positive, Neutral, Negative, Very negative. From this crude analysis a decision can be made to eliminate some alternatives and include new ones, for further detailing and analysis. Frequently, such crude analyses give the necessary platform for choosing one appropriate alternative.

   When considering a set of possible risk reducing measures, a qualitative evaluation in many cases provides a sufficient basis for identifying which measures to implement, as these measures are in accordance with good engineering or with good operational practice. Also many measures can quickly be eliminated as the qualitative analysis reveals that the burdens are much more dominant than the benefits.
2. From this crude analysis the need for further analyses is determined, to give a better basis for concluding on which alternative(s) to choose. This may include various types of analyses of risk.
3. Often the risk analysis focuses on the possibility of loss of lives. Then the risk analysis presents a risk picture related to this consequence, and this risk picture is compared with relevant other activities, analyses and data. From this evaluation, the analysis group has a basis for giving a statement about how they judge the risk. The analysis group does not conclude on whether risk is acceptable or not, as acceptance is related to the alternative considered, with all benefits and burdens associated with it, and not only the risk level.
4. Other types of analyses may be conducted to assess for example costs, and indices such as expected cost per expected saved statistical lives could be computed to provide information about the effectiveness of a risk reducing measure or compare various alternatives. The expected Net Present Value may also be computed when found appropriate. Sensitivity analyses should be performed to see the effects of varying values for statistical lives and other key parameters.

   Often the conclusions are rather straightforward when calculating indices such as the expected cost per expected saved lives over the field life and the expected cost per expected averted ton of oil spill over the field life. If conclusion about gross disproportion is not clear, then these measures and alternatives are clear candidates for implementation.

   Clearly, if a risk reducing measure has a positive expected net present value it should be implemented. Crude calculations of expected net present values, ignoring difficult judgments about valuation of possible loss of lives and damage to the environment, will often be sufficient to conclude whether this criterion could justify the implementation of a measure. This has been documented by e.g. [22].
5. An evaluation of other factors such as risk perception and reputation, should be carried out whenever relevant, although it may be difficult to describe how these factors would effect the standard indices used in economy and risk analysis to measure performance.
6. A total evaluation of the results of the analyses should be performed, to summarize the pros and cons for the various alternatives, where considerations of the constraints and limitations of the analyses are also taken into account.
7. The decision maker then performs a review and judgment of this decision support and makes a decision.

The essential element in the above decision process is a drive for generating alternatives. Often a base case is defined, but the successful implementation of this regime is that there is a climate for considering possible changes and improvements compared to the base case. If risk to personnel or the environment is considered relatively high, solid arguments will be required not to improve or eliminate the alternative. The difference in costs should be grossly disproportionate if no safety improvements should be made. If an alternative is chosen with a rather high risk level, the decision maker must be able to document the arguments in the case of a later scrutiny, for example as a result of an accident.

It is essential that the analysis team has the ability to communicate the information from the analyses to the decision-maker, and the decision-maker must understand what the analyses and the analysts express. Compared to the present situation, there is a need for improvements on both these areas. It is also necessary that the results from the analyses are communicated to management at a sufficiently high level. Implications of risk results may sometimes be far reaching, with facets that are non-tangible, and with certain dimensions of a political nature. It is therefore important that the risk results are communicated directly to a high management level, and not filtered through several layers of middle management.

Compared to a regime based on the use of risk acceptance criteria, the above regime could in some cases mean a more direct visualization of the decision-maker's trade-offs between safety and other aspects, such as costs. Some may think this is appropriate, but it could also be a problem – not all decision-makers would see this as attractive. Risk acceptance criteria means an extended level of delegation to lower levels of decision-making.

4. The Case Study

The case study considers an offshore oil field on the Norwegian Continental Shelf**,** implying considerable challenges for the protection of personnel as well as the environment. Personnel need protection against harsh environmental conditions, also during an emergency. Possible oil spills may, if not contained, have environmental effects. Economically, the field is considered to be a so-called 'marginal field', implying that field development costs must be strictly controlled, in order to ensure a reasonable profit from the investments in field production systems. The currently most favorable production system is conversion of an existing crude oil shuttle tanker, to become a Floating Production, Storage and Off-loading (FPSO) system. The fact that an existing vessel design will be used, implies some vessel characteristics that are uncommon, when compared to purpose built FPSO vessels. The main differences may have impact on the safety of the personnel onboard.

The operator's principles for risk acceptance have been expressed with the main emphasis on performing evaluations in order to demonstrate that the risk levels are as low as reasonably practicable (ALARP evaluation).

A relatively coarse Concept Safety Evaluation was initially performed in a traditional manner, mainly limited to risk exposure of personnel. Extensive result presentations were generated as input to the ALARP evaluation.

Another exercise that was conducted as input to the evaluation was to perform an analysis whereby the risk results of the proposed converted vessel was compared to risk results of other FPSO vessels, in order to identify how the results would be ranked against vessels which could be regarded as 'current practice' FPSOs. Fig. 1 presents one of these comparisons, where the case study FPSO at the left in the diagram is compared to three other FPSOs. The results show that the concept in spite of some uncommon features compares favorably to some other FPSO concepts.

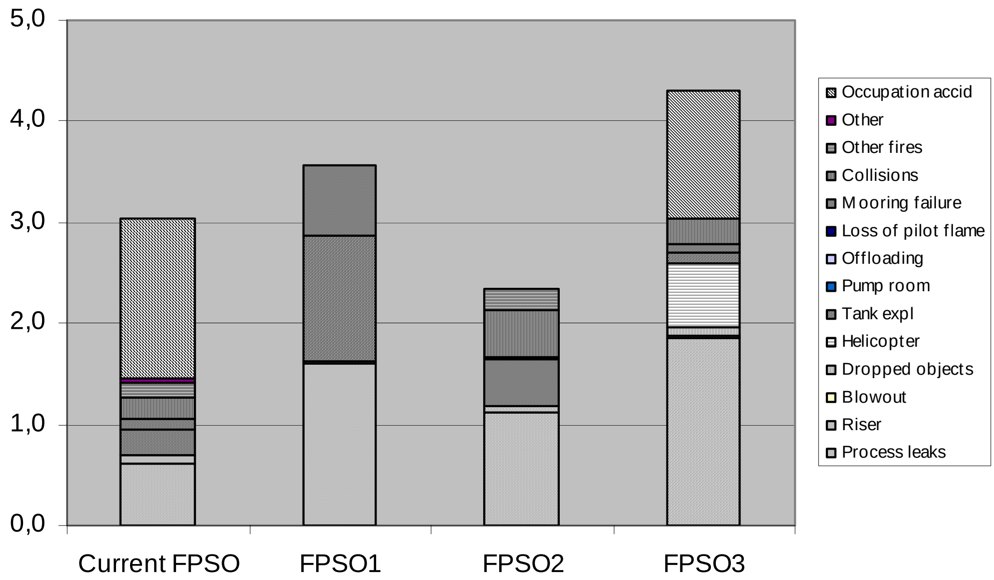

Fig. 1 Comparisons of FAR risk for FPSOs.

4.1 Risk assessment process

The risk evaluation process based on the ALARP approach shall ensure that overall evaluations are performed in order to arrive at solutions that are in accordance with authority requirements and expectations, internal company requirements and accepted industry practice. It is required that the following aspects are addressed:

1. Are all authority requirements satisfied?
2. Are all internal requirements met?
3. Is the analysed risk level on par with that of comparable concepts/solutions?
4. If some requirements or practice are not met, can it be demonstrated that the concept after all does not have an increased risk level?
5. If quantitative targets are defined, are these met with sufficient margin, in order to enable any possible later increased in analysed risk levels, without need for extensive changes?
6. Is Best Available Technology (BAT) used?
7. Have solutions been chosen with inherent safety standards?
8. Are there any unsolved problems or areas of concern with respect to risk to personnel and/or working environment, or areas where these two aspects are in conflict?
9. Are there any unsolved problems in relation to serious environmental spill?
10. Is the concept robust with respect to safety?
11. Are aspects of newest possible R&D results and other new experiences considered?

The risk evaluation process consisted of the following main steps:

1. Identification of potential safety improvements that could be applied to the concept, focusing especially on unconventional aspects.
2. Qualitative evaluation of design and operational aspects with a view to the potential benefits of the risk reduction proposals, also focusing on the aspects 1-11 listed above.
3. When all measures that may be justified on the basis of these evaluations have been

exhausted, coarse cost/benefit evaluations should be performed.

The first step here resulted in almost 40 risk reduction proposals being identified, mainly limited to conceptual aspects. The following themes were addressed:

- Overall Layout
- Structural and Marine Aspects
- Subsea Production Systems
- Process Plant Layout
- Turret and Swivel Systems
- Storage and Export Systems
- Offloading Arrangements and Operations
- Safety Systems
- EER Systems
- Management of Emergencies

The results of the qualitative evaluations in Step 2 were recommendations to incorporate almost 80 % of the proposals into the concept design.

The third element on the list above, is the quantitative element, during which the following evaluations are performed:

- Identify possible technical and/or operational improvements that may reduce risk to personnel or environment, but which implies substantially increased capital or operational costs or other operational drawbacks.
- The following assessments are made for these alternatives:

  1. Overall net present value of all costs and income per statistical fatality averted
  2. Cost distribution (material damage and delayed/deferred production income) for relevant years, given the occurrence of a major accident, with respect to scenarios that are influenced by the measures being considered
  3. Overall net present value of all costs and income per statistically expected reduced 1000 tons of oil spill
  4. Cost distribution (clean up costs, compensation claims, etc) for relevant years, given the occurrence of a major oil spill, with respect to scenarios that are influenced by the measures being considered
  5. Loss of reputation for relevant years, for relevant years, given the occurrence of a major accident or major oil spill, with respect to scenarios that are influenced by the measures being considered.

4.2 Case illustration of robustness

As an illustration of the evaluations that are being made in order to assess the risk aspects and the improvement potentials, consider the following discussion of Item 8 in the list above, focusing on the robustness of the proposed vessel concept.

There are several aspects that are important for the robustness of the concept with respect to safety. The use of the Submerged Turret Loading (STL) system is one of these, whereby the transfer of the streams from flowlines to the weather vaning FPSO is considered to be simplified, thus reducing the probability of leaks.

The downside of the STL is that consequences of possible explosions will be more severe, due to the enclosed area. It is also more difficult to design against such consequences, due to the lack of possibilities to relieve the possible blast overpressures. The proposed addition of coffer dams towards the cargo section will compensate to some extent.

Overall, the STL concept is considered to be an aspect of robustness, as reduction of leak probability should be given the highest priority.

The second aspect to be considered in relation to robustness is the accommodation in the stern of the vessel, whereas all other FPSOs in Norwegian waters have accommodation in the bow. The location of the quarters has been discussed thoroughly, and it was concluded that the advantages implied by moving the accommodation to the bow (in practice a purpose built vessel might have been the solution in order to meet this requirement) are not sufficiently high in order to justify the high costs that would be incurred.

It is therefore concluded that the concept may be considered robust with respect to protection of personnel in the quarters, in spite of the location of it aft on the FPSO. This conclusion is strongly dependent on the distance of more than 100 metre between the process plant and the accommodation, and will change if the distance is significantly reduced.

The third aspect where robustness has to be considered, is the use of conventional off-loading pumps in stead of deep well off-loading pumps individually in each of the 12 cargo tanks. The evaluation of possible installation of deep well pumps concluded that the costs would be unjustifiable in relation to the benefits implied by removal of pump room explosion risk. It was argued that use of deep well pumps in addition to eliminating pump room explosions, also would reduce the likelihood of fires on deck associated with leaks from the piping manifold, due to maloperation of valves.

Whereas the use of deep well pumps was not recommended based upon an isolated evaluation, the assessments in relation to other aspects underline that deep well pumps are considered Best Available Technology, they are considered inherently safe, and they contribute to the robustness of the concept.

It is on this basis concluded that the combination of quarters aft and use of conventional pump room implies too severe a deterioration of the robustness of the proposed FPSO concept. Cargo tanks, piping and manifold on deck, pump room and engine room are all sources of fire or explosion which may severely affect the accommodation. Replacement of the conventional pumps by deep well pumps in each cargo tank is considered to be the easiest and least expensive action to take, which actually eliminates one of the fire sources, and reduces another. The CAPEX cost in the order of 30 million NOK is not considered to be excessively preventative.

Replacement of conventional off-loading pumps in the pump room with deep well pumps in individual cargo tanks is therefore recommended based upon a balanced evaluation of all aspects involved. A summary of the assessments is presented in the following subsection.

4.3 Illustration, cost-benefit evaluation

An evaluation of costs and benefits (reduced accident consequences) was performed in order to explore whether the installation of deep well pumps is justifiable. The values used are expected values of the uncertainty distribution for the costs and benefits, this is however not repeated for every value.

A complete package of deep well pumps, hydraulic power pack and distribution system, control system and slop tank pumps was claimed by a supplier to have an equipment cost around 30 million NOK. Additional operations and maintenance (OPEX) costs have been estimated to 0.1 million NOK per year.

The Net Present Value of CAPEX and OPEX over 10 years is 30.6 million NOK. This implies that rough estimates may be used for OPEX, as CAPEX is dominating completely, when extra costs are considered. These values are taken without tax consideration as recommended by NORSOK Z-013, and as costs for the project, without considering the operator’s or any other company’s license share.

The PLL contribution from the pump room is $8.6 \cdot 10^{-4}$ per year, according to the risk analysis conducted. The risk contribution to assets is usually dominated by production delay, and other contributions have therefore been disregarded. Table 1 gives the contributions to production delay risk originating from the pump room, for the categories used in the study.

Table 1. Overall Results – Production Delay Risk

Hazard	Downtime Category			
	Minor damage	Medium damage	Major damage	Catastrophic damage
Pump room fire & explosion	8.70E-05	1.40E-05	5.10E-06	8.00E-07

A detailed economic analysis would simulate such an accident in each year, calculate the actual production delay, assuming for instance that a 6 month downtime is recaptured at the end of the field lifetime, which implies that the delay will vary from 10 years down to 0 years, according to when the accident occurs. The actual loss is then the difference in NPV between the year the accident occurs and the end of the field lifetime. The approach in this regard is simpler, as indicated above.

With the assumptions given, the annual expected loss from pump room accidents is 0.016 million NOK/year. The NPV of expected losses from the 10 year period is 0.1 million NOK. This is a low value, when the NPV of CAPEX and OPEX is 30.6 million NOK.

The summary of the proposed reduction is as follows:

- Expected NPV of CAPEX and OPEX: 30.6 million NOK
- Expected NPV of reduced production delay costs: 0.1 million NOK

Given the fixed discount rate, the uncertainties in the CAPEX and OPEX values are rather small, meaning that the above values are considered to give accurate estimates or predictions of the actual CAPEX and OPEX values, if deep well pumps are in fact being installed. One uncertainty element is related to the extent of the investment, whether some residual value is considered after 10 years, etc.

The "benefit", i.e. the risk reduction is highly probabilistic, actually there is a low probability of having an accident in the pump room, but if it occurs, the consequences are likely to be rather severe. If a pump room explosion occurs, the following are expected consequences:

- Fatalities per explosion: 8.1 persons
- Production delay per explosion: 18.2 days
- Lost income per explosion: 149.9 million NOK

The probability of having a pump room fire/explosion is $1.1 \cdot 10^{-4}$ per year, which then is estimated to have expected losses as stated above. There is a probability equal to $8.0 \cdot 10^{-7}$ per year to have so severe damage to the FPSO that it is classified as total loss, in which case the production delay is more than one year. If the overall annual expected values are calculated, the results become:

- Fatalities (PLL): $8.6 \cdot 10^{-4}$ per year
- Lost income: 0.016 mill NOK per year

The expected cost per saved statistical life may then be calculated from expected NPV of 30.5 million NOK and reduced PLL as stated above per year. For a 10 year period the value (no depreciation of future losses in terms of life) is 0.0086 fatalities. The value is 3 534 million NOK/life.

Several of the values that are used in the assessment are rather uncertain quantities, such that the values may change quite considerably. It is therefore worth considering how much the expected cost per saved statistical life may change under different assumptions. With the high value as given above, it is most interesting to see how much lower the cost/life could be.

It the cost/life is reduced by a factor of 50 or more, this may (refer to the discussions below) alter the conclusions. It has been argued that the CAPEX is the least uncertain value, it will probably be in the range 20 – 50 million NOK whatever assumptions that are taken.

The number (frequency) of fires and explosions in the pump room is rather uncertain. There is considerable experience data from commercial tankers, also in crude transportation, but the experience with FPSOs with conventional pump room is relatively limited. There has never been an FPSO with pump room fire/explosion.

It was demonstrated in the original analysis that the frequency of pump room accidents on commercial tankers was higher in the 1980-ties, by a factor of 5-6. An upper limit for the frequency could be based on such experience.

The value taken as expected number of fatalities per accident is quite high, above 8 persons per occurrence. There may be quite extensive uncertainty associated with the number of fatalities per accident, but the upper limit is obviously a function of the number of persons exposed to the effects. An upper limit could be twice the value used.

The lower limit cost per saved statistical life is with these assumptions 208 million NOK/life. OPEX and production delay costs have been disregarded from this sensitivity assessment, due to the low influence on the results. The value 208 million NOK/life is a lot lower than the expected value, and reflects special circumstances, where the cost is reduced considerably, and the risk values are quite high. The risk values are in fact so high that one would have expected an occurrence of this kind from world wide operations.

4.4 Final remarks on case study

Most of the recommendations made for the proposed FPSO concept were proposed for implementation. When the ALARP evaluations had been completed, between 80 and 90 % of the proposed improvements had been recommended for implementation.

It should be noted that this rather extensive identification of risk reduction measures was achieved without the use of fixed limits for risk acceptance. The use of risk acceptance criteria is not considered as prerequisite for successful risk reduction, as outlined in Section 3 above. This is similar to the experience from the case study discussed in [22].

Based on the discussions and evaluations it was concluded that the risk to personnel implied by the FPSO concept design was as low as reasonably practicable, assuming that the recommended actions are implemented. This conclusion applies to the global design concept and the main parameters.

It should be noted that the ALARP demonstration applies in the present case to the optimization of the FPSO concept. The selection of the production concept is not discussed in this context.

It is further emphasized that detailed design solutions and operational procedures have not been considered with a view to reducing the risk level as far as reasonably practicable. The process will therefore need to be continued through design, fabrication and installation phases.

Conclusions

We have argued for a goal oriented management using high level goals, generation of alternatives, analysis and evaluation of these. As a principal view we have argued against the use of pre-defined requirements and criteria. The point is that such requirements and criteria imply that the question about what is acceptable from a safety perspective is sought solved without the use of holistic evaluations involving all relevant attributes. An approach based on pre-defined requirements and criteria restricts the political flexibility, and it means a considerable element of arbitrariness.

Nonetheless, it is acknowledged that in practice there is a need for some type of requirement in the development phases to simplify the planning processes. Such requirements relate to the goodness of safety systems and safety functions. Care has however to be shown when using such requirements such that sub optimisation is avoided, there should always be drive for generating alternatives. See [4].

It should also be acknowledged that implementation in an engineering project, especially in 'fast track' projects, will be a demanding task, in order to ensure that relevant risk reducing measures are considered.

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