Oil & Gas UK
the voice of the offshore industry

Guidance on Risk Related Decision Making

Issue 2
July 2014

Acknowledgements

In preparing and publishing these Guidelines, Oil & Gas UK gratefully acknowledges the contribution of members of the work group, namely:

David Piper – Maersk Oil (Work Group Chair)
Paul Renwick – Amec
John Morgan – DNV GL
Mike Johnson – DNV GL
Bob Lauder – Formerly Oil & Gas UK
Chris Wicks – Marathon Oil
Tommy Spence – Marathon Oil
Rebecca Borresen – Oil & Gas UK

ISBN: 1 903 004 32 2

PUBLISHED BY OIL & GAS UK

London Office:
6th Floor East, Portland House, Bressenden Place, London, SW1E 5BH
Tel: 020 7802 2400 Fax: 020 7802 2401

Aberdeen Office:
Exchange 2, 3rd Floor, 62 Market Street, Aberdeen, AB11 5PJ
Tel: 01224 577250 Fax: 01224 577251

Email: info@oilandgasuk.co.uk
Website: www.oilandgasuk.co.uk

Table of Contents

Abbreviations

ACoP	Approved Code of Practice
ALARP	As Low As Reasonably Practicable
CBA	Cost Benefit Analysis
DECC	Department of Energy and Climate Change
EER	Escape, Evacuation and Rescue
ESDV	Emergency Shut Down Valve
HSE	UK Health & Safety Executive
NFPA	National Fire Protection Association
OGP	International Association of Oil and Gas Producers
PLL	Potential Loss of Life
POB	Personnel on Board
PSV	Pressure Safety Valve
QRA	Quantitative Risk Assessment
SSIV	Subsea Isolation Valve
UKOOA	United Kingdom Offshore Operators' Association

1 Introduction

The upstream oil and gas industry in the UK operates within a goal-setting regulatory framework in relation to health and safety. This places a responsibility on those in the industry to set out and justify the basis for managing the risks in their operations.

This guidance is designed to facilitate risk related decision making by providing a common understanding of the bases upon which risk related decisions are made. It provides a structured framework that enables business, technical and societal factors to be considered and used to establish a transparent and justifiable basis for decision making.

The principal application of the framework is likely to be for decisions in the context of major accident hazards, during the design, operation and decommissioning of offshore installations and other oil and gas facilities. It may also be applied to safety and environmental decisions where the risk may not arise specifically from major hazards.

This guidance was developed by a work group of the Oil & Gas UK Major Hazards Management Forum and:

- Is fully aligned with UK legislation and regulatory guidance;
- Is primarily focused on major accident hazards;
- Takes account of environmental risk; and
- Promotes senior leadership understanding as well as providing guidance to practitioners.

This guidance replaces the UK Offshore Operators Association (UKOOA) document "Industry Guidelines on A Framework for Risk Related Decision Support" – Issue 1, May 1999 and builds on the experience gained since 1999, reflecting both changes in the regulatory environment and the increasing maturity of risk related decision making[1].

2 Purpose and Application

The purpose of this guidance is to define a framework that provides a sound basis for making a risk related decision and justifying it to stakeholders. The framework is intended to provide transparency on how factors that may affect the decision are taken into account. It helps to define the context of the decision and assists in the identification of methodologies to allow a decision to be made.

The framework is most applicable to the more critical or difficult decisions relating to major accident hazard management and can be adapted to suit the situation at hand. The framework is unlikely to be applied to the more straightforward decisions that involve following accepted codes, standards and good practice, although for completeness, such decisions are catered for within the framework.

This document represents good industry practice for risk related decision making. It is not mandatory, although it does refer where appropriate to certain UK legal requirements and other HSE and industry publications.

[1] In addition, given that one of the critical criteria for a decision is that it can be made with sufficient certainty, this document also includes relevant information from the now withdrawn *HS005 - Guidelines for Quantitative Risk Assessment Uncertainty - Issue 1 (March 2000).*

3 Regulatory Context

This guidance has been written in the context of the regulatory regime applicable to the UK upstream oil and gas industry and, in particular, the requirement that risks should be reduced to as low as reasonably practicable (referred to as the 'ALARP principle'). The UK Health & Safety Executive (HSE) has published authoritative guidance both on the theory of ALARP and on its expectations in demonstrating that risks have been reduced to ALARP [1, 2, 3, 4]. In providing a framework for risk related decision making, this guidance aligns with and supports those expectations.

It is also anticipated that this guidance will remain valid following UK implementation of the EU Directive on the safety of offshore oil and gas operations [5] because the Directive includes the concept of ALARP, which is also the basis for this framework. The Directive's inclusion of "*major environmental incident*" within the definition of a major accident broadens the application of this guidance to include consideration of potential environmental incidents. Environmental benefits should be considered alongside the safety benefits of a risk reduction measure, especially when the potential consequences are high.

4 Risk Management

Within the risk management process for a facility or company, there will be specific issues that arise with risk implications and a range of options for addressing these risks. As already described, the framework gives a structure to the process of option selection that allows the basis of the decision to be understood and justified.

The overall risk management process must, as a minimum, meet regulatory requirements. Within the UK, this requires that:

- The individual risk is below the upper tolerability limit and, when this is satisfied,
- The overall risk is reduced to a level that is ALARP.

The principle of ALARP is fundamental to the application of the framework. The framework gives a structured approach to the determination whether it is reasonably practicable to implement a risk reduction option. Where different options exist, the framework assists in deciding on the measures that should be implemented.

The following statement from the HSE defines what is reasonably practicable [2]:

> *In any assessment as to whether risks have been reduced ALARP, measures to reduce risk can be ruled out only if the sacrifice involved in taking them would be grossly disproportionate to the benefits of the risk reduction.*

In assessing whether there is gross disproportion between the sacrifice (in money, time and trouble) and the risk benefit, a process needs to be applied that allows the decision to be made with sufficient certainty. This requirement means that different assessment techniques will be applicable for different decisions, with the general concept that a more difficult decision is likely to need a more complex assessment technique. Competent judgement is likely to be required in identifying suitable analysis and assessment methods and in interpreting the results. Any risk assessment should be "*suitable and sufficient*" and "*the rigour of assessment should be proportionate to the complexity of the problem and the magnitude of risk*" [6].

The risk management process may also introduce other factors that affect the application of the decision framework. For example, if the risk management process includes an aversion to high consequence events, this may result in decisions that go beyond what would be required from a purely ALARP consideration. High consequence in this context is not just restricted to harm to people, but includes environmental, reputational and financial considerations.

Key elements of risk management are highlighted here and discussed where relevant within the description of the framework in Section 5.

4.1 Hazard Identification

A critical part in any risk management process is hazard identification. The failure to identify a hazard will prevent effective management and may fundamentally flaw any decision made using the framework. Guidance on hazard identification is given in [7] and [8] and is not repeated here.

4.2 Risk Tolerability

The end result of any risk management process must be such that the risk to all individuals exposed to the hazards lies below the upper tolerability limit (and is ALARP). The upper tolerability limit for risk of fatality to an individual is suggested in [1] as 10^{-4} per annum for the public and 10^{-3} per annum for workers, who are assumed to accept a greater element of risk due to directly benefiting from the activity.

However, other than in exceptional circumstances, risk-related decisions on specific issues will have relatively little impact on the total facility risk, as they affect only a small subset of risk contributors and thus the need to meet tolerability criteria will rarely impact the decision making process.

This may not be the case in situations where there are significant risk uncertainties and high potential consequences. In such circumstances, evaluation of the risk may suggest that it is below the upper tolerability limit, but this may not be known with sufficient certainty. This situation will often require a precautionary approach, as discussed further in Section 5.3.3.

Tolerability considerations alone can provide a risk-related decision only in the case where a single available option lies below the upper tolerability limit. Any option selected on this basis will also need to meet good practice.

Case 5 in Appendix A describes a situation where a risk-related decision depends largely upon the need for the risk to be below the upper tolerability criteria.

4.2.1 Other Risk Measures

While individual risk is the most widely used measure for risk tolerability, there are a number of other risk measures that are routinely used in risk based decision making, including:

- *Societal Risk* – provides an understanding of the exposure to events with the potential to cause multiple fatalities. Can be plotted as FN curves, which show the frequency (F) of events that cause N or more fatalities.

- *Potential Loss of Life (PLL)* – the average number of fatalities per year. Cost benefit analysis uses the change in the PLL provided by a risk reduction measure to determine if the measure is reasonably practicable.
- *Impairment Frequency* – is the frequency that a critical item is unable to fulfil its function and can be used as a design or tolerability criterion.

Societal risk tolerability limits may be applied, though this is more often the case for onshore facilities which present a potential risk to the public. Tolerability criteria can also be set for impairment frequencies. It is not uncommon for operators to set their own criteria for risk tolerability. Guidance on developing risk criteria is given in [9].

4.3 Good Practice

Good practice provides a clear indication of reasonably practicable risk management measures for situations where the hazard is relatively well understood and is often embodied in codes and standards. Where established good practice exists, this needs to be met, or an equivalent measure provided, in all circumstances. This is a key part of the framework and is considered further in Section 5.3.1.

4.4 Hierarchy of Risk Reduction Measures

Even if the risk reduction achieved is the same, there is a preference given to hazard avoidance and prevention compared to control and mitigation. This leads to a hierarchy of risk reduction measures (in decreasing order of preference):

- Elimination and minimisation of hazards by design (inherently safer design);
- Prevention (reduction of likelihood);
- Detection and control (limitation of scale, intensity and duration);
- Mitigation of consequences (protection from effects); and
- Evacuation, escape and rescue (EER) arrangements.

It is likely that a combination of these measures will be used to manage any given hazard.

4.5 Risk Management Guidance

4.5.1 Option Dependence

The methods to be used in the demonstration that a selected option reduces risks to a level that is ALARP are discussed in Section 5.3. At this point, it should be noted that there can be some dependence between options. For example, two options may be available, one relatively simple and low cost, the other more complex and higher cost, but giving greater risk reduction than the first. Taken on its own, the second option would be considered reasonably practicable; however, after implementation of the first option, it might not (i.e. the additional quantum of risk reduction might not be required for the risk to be ALARP). In these circumstances, other factors may form part of the decision process, for example the level of certainty associated with each risk reduction measure and their position in the hierarchy described above.

4.5.2 Avoidance of Reverse ALARP

Good practice is considered as part of the framework in Section 5.3.1, but important guidance on the avoidance of *reverse ALARP* is given here.

An argument could be constructed that, for reasons such as the short remaining life of an asset, the re-instatement cost of a previously functioning risk reduction measure is grossly disproportionate to the risk benefit that it would achieve. This is commonly called *reverse ALARP*. In this case, the test of good practice must still be met and, since the risk reduction measure was initially installed, it must constitute good practice to reinstall or repair it. Reverse ALARP arguments are not appropriate in an ALARP demonstration.

This does not prevent a suitably justified decision not to re-instate a risk reduction measure if the original reason for installing it changes due to, for example, elimination of the hazard for which it was a risk reduction measure.

4.5.3 Representing the Real Risk

All risk assessment methodologies rely on input data. Whilst the use of generic data may be appropriate in the design stage or as a starting point for operating assets, it is important that the reality of the condition of any operating asset is taken into account. This is particularly important with ageing assets with known integrity issues, or where adequate inspection data is not available. The use of generic data in these circumstances is unlikely to give a true representation or measure of the risk and either asset specific information should be used, or the uncertainty recognised.

4.5.4 Risk Transfer

In assessing different options, care should be taken to ensure that *all* of the risks to people are taken into account. A narrow view of the people affected can result in an option being selected that appears to give the best solution, but actually transfers risks to another group not considered within the assessment. For example, the retrospective installation of an SSIV on a stabilised crude oil line might reduce risks to personnel on the platform but will introduce risk to the divers installing it.

4.5.5 Uncertainty

Within the risk management process, and key to this framework, is a requirement that any risk-related decision must be made with sufficient certainty. This is particularly relevant where a clearly safer option is not chosen, or there is sufficient uncertainty in the analysis to allow for a possibility that the selected option does not meet risk tolerability criteria. In establishing that risks are tolerable, the margin between assessed risk levels and tolerability criteria must be shown to significantly exceed any uncertainty in the risk assessment.

In determining the risk, the impact of realistic changes to inputs to the assessment and the assessment techniques themselves must be determined, if there is a possibility that they would change the result of the assessment. This does not mean that all parameters in the assessment need to be varied as some may have a small effect on the final risk figure. Additionally, if there are potentially severe consequences, the risk assessment should be conservative, making it unlikely that uncertainties in the parameters result in a less-safe option being chosen.

5 The Decision Making Framework

5.1 Decision Context

The first step in applying the framework is to determine the decision context, i.e. the combination of circumstances, knowledge, events and attitudes within which the decision is to be made.

Many factors and constraints will be important in determining the decision context. Those considered key to the framework are listed below:

- The novelty and type of the proposed operations, technology, approach or methods;
- The perceived risks and opportunities (i.e. the magnitude and likelihood of potential safety, environmental, economic, business or other outcomes, whether beneficial or adverse) associated with the decision, and the degree of certainty with which these can be assessed;
- The views, attitudes and perceptions of government, the public and other stakeholders towards the decision that is being made.

Guidance is given below on how the above factors may affect the decision context.

Once the decision context has been determined, the framework (Section 5.2) can be used to guide the selection of methods, or combinations of methods, likely to provide the most appropriate basis for risk related decision making.

5.1.1 Type of Activity

The type of activity to be undertaken, and the novelty of the operations, technology, approach and methods involved, will affect the decision context. The risk associated with common, well-understood situations is more likely to be controlled by the application of good practice, while less common situations will need risk assessment. For novel operations or technology the approach is more likely to be precautionary as described in Section 5.3.3.

5.1.2 Risk and Uncertainty

As outlined in Section 4.5.5, a decision must be made with sufficient certainty. Hence, factors that affect the certainty of the risk assessment process and results will also affect the decision context. Decisions made by reference only to good practice require a high degree of certainty as to the risks and their management. Increasing uncertainty implies a need to consider other assessment techniques.

5.1.3 Stakeholder Influence

Risk related decisions are made by owners, operators or other duty holders, but will also be of interest to stakeholders such as the workforce (including the technical community), partners, regulators, non-governmental organisations, shared interest groups and society at large.

The extent to which stakeholders have an interest in the decision will depend on the nature of the risk (e.g. its magnitude, complexity or uncertainty) and the stakeholder perception of that risk. This in turn drives the degree of stakeholder influence and therefore the decision context and the way in which the decision will be made.

For example, where the risk is addressed by relevant good practice, stakeholders will generally not have a significant interest in the decision, provided the good practice is being followed. A stakeholder, e.g. a partner, may wish to influence the choice of code or standard that is used to define good practice, but the risk impact of the code choice is likely to be neutral.

In contrast, stakeholders, such as partners and regulators, may have a keen interest in a decision that is complex or highly uncertain, or where the decision has significant risk impact, such as in concept selection. The views, concerns, perceptions and values of stakeholders will normally be taken into account in such circumstances, and are likely to move the decision context such that the decision is made by a process that is either more rigorous, or more conservative.

The role of stakeholders may be particularly relevant in an environmental context, such as for pollution risks. In some cases, stakeholder values may lead to a more conservative decision than would otherwise be the case.

5.2 The Framework Diagram

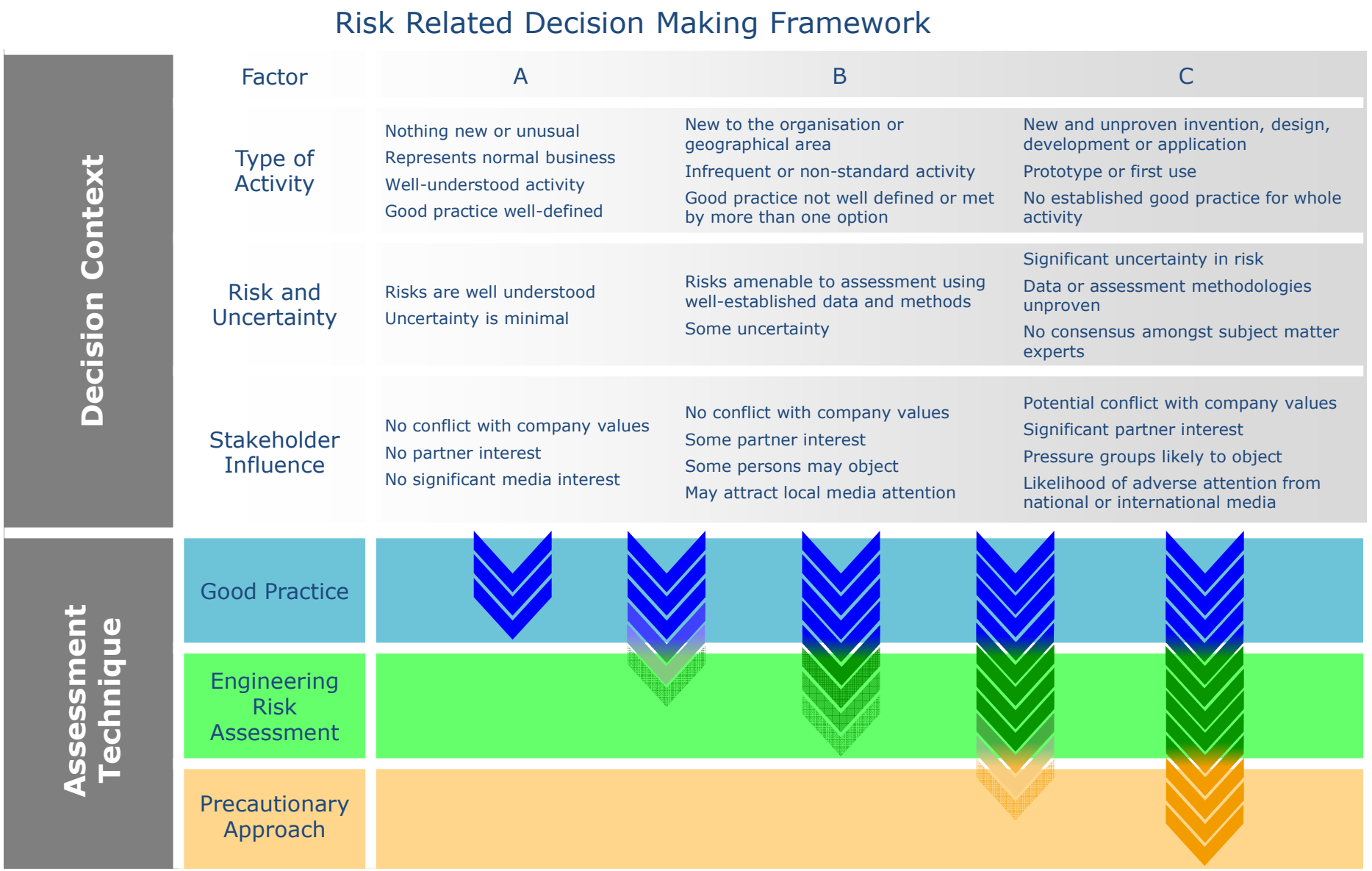
For different decision contexts, the risk related decision making framework diagram (Figure 1) suggests the techniques that allow a risk related decision to be made with sufficient certainty.

In Figure 1, three different decision contexts (A, B and C) are shown for simplicity of presentation and a series of guide phrases, based on the factors above, aid in assigning the context type to a given decision. However, in reality, there is a continuum of context ranging from the most mundane decision to the most complex.

- For a type A decision, where the risk is relatively well understood, in general the decision will be determined by the application of recognised good practice. In cases where good practice may not be sufficiently well-defined, engineering risk assessment may be required to guide the decision.
- For a type B decision, involving greater uncertainty or complexity, the decision will not be made entirely by established good practice. Thus while any applicable good practice will have to be met, there will also be a need for engineering risk assessment in order to support the decision and ensure that the risk is ALARP.
- A type C decision will typically involve sufficient complexity, uncertainty or stakeholder interest to require a precautionary approach. In this case, relevant good practice will still have to be met and detailed engineering risk assessment will be used to support the decision.

The chevrons in the diagram show the technique(s) likely to be needed to make the decision. Whatever the context, good practice must be met and the risk must not to be intolerable. For A decision contexts, this may be sufficient to make the decision. Moving towards decision context B means that engineering risk assessment is likely to be needed to make the decision. For A/B, B and B/C decision contexts, the arrow strength diminishes towards the base of the arrow to show the reduced relevance of that technique for such a decision. Towards and in decision context C, the precautionary approach is likely to be needed to make the decision and, for this, engineering risk assessment will be needed to inform this approach. The colour is graded for the decision contexts to indicate that A, B and C are representative of a continuum of context.

Figure 1: Risk Related Decision Making Framework



5.3 Decision Methods/Approaches

Once the decision context has been determined, the methods or approaches on which the decision is likely to be based are illustrated in the framework diagram. The following sections describe each of these methods.

5.3.1 Good Practice

Where good practice exists, or a measure that gives an equal or better outcome, it must be followed. Therefore if a number of risk reduction options are being considered only those that meet or exceed relevant good practice should be taken forward.

The HSE defines good practice within its 'ALARP trilogy' [2, 3, 4], which states:

> *Within HSE, good practice is the generic term for those standards for controlling risk which have been judged and recognised by HSE as satisfying the law when applied to a particular relevant case in an appropriate manner. Sources of written, recognised good practice include: HSC Approved Codes of Practice (ACoPs); HSE guidance; guidance produced by other government departments; standards produced by standards-making organisations (e.g. BS, CEN, CENELEC, ISO, IEC); guidance agreed by a body representing an industrial/occupational sector.*
>
> *In judging compliance, HSE expects duty-holders to apply relevant good practice as a minimum. For new plant/installations/situations, this will mean the application of current good practice. For existing plant/installations/situations, this will mean the application of current good practice to the extent necessary to satisfy the relevant law.*

In this document, good practice is defined as [6]:

> *The recognised risk management practices and measures that are used by competent organisations to manage well-understood hazards arising from their activities.*

The second definition is used as it encompasses the first and allows for a consensus of good practice to be developed without reference to the regulator.

Good practice may change over time or because of increased knowledge about the hazard and/or a change in the acceptability of the level of risk control achieved by existing good practice. To be consistent with HSE guidance, operators should consider if implementing any new good practice is reasonably practicable when applied to their existing facility.

Note that good practice in itself may require carrying out a risk assessment. For example, BS EN 61511 for instrumented systems would be considered to represent good practice and embodies an approach based on risk assessment.

5.3.2 Engineering Risk Assessment

Where good practice is not well-defined or where the particular circumstances are not fully within the scope of current good practice, a more detailed engineering risk assessment that takes account of the specific circumstances of the decision is required. Such an assessment may involve the use of a range of techniques and will require an understanding and application of sound engineering and scientific principles and methods, such as:

- Engineering analysis (e.g. structural, fatigue, mooring, process simulation);
- Consequence modelling (e.g. fire, explosion, ship collision, dropped object);
- Risk assessment (semi-quantitative or quantitative);
- Reliability analysis (e.g. fault tree, structural reliability methods); and
- Cost benefit analysis.

While risk assessment is often needed to make the decision, if a decision can be made based on consequence alone, there may be no need to reference the frequency of an event. For example, if a facility can be designed to withstand the maximum possible explosion overpressure, there is no need to determine the frequency with which this might occur.

Should it not be possible to eliminate the hazard, a risk assessment needs to be carried out to ensure that the remaining risk is ALARP. There is a spectrum of techniques available to carry out a risk assessment, from the relatively simple, such as a risk matrix, to the more complex, typically fully quantified risk assessment. HSE guidance [6] lists the main factors that affect the level of sophistication of risk assessment that should be used and, of relevance to decision making, the key is that the risk assessment is able to differentiate between different options.

In terms of deciding between options, differentiation is required such that the benefit of the risk reduction measure can be seen and the reason for the benefit understood. Thus, for example, a risk matrix is a good tool for making decisions in relation to workplace risks, but is an inappropriate tool to justify a decision not to install an SSIV. Conversely, a quantified risk assessment would not be beneficial for most workplace risks, as it would not be possible to find sufficient accurate data to show difference between risk reduction options, but it could be used to show the risk reduction gained from an SSIV. Further guidance is given in [6] and [7] and, where the case studies in Appendix A use engineering risk assessment, the type of analysis is described and justified.

Once a risk assessment has been undertaken, reasonable practicability may be shown by demonstrating that the residual risk is negligible, or a cost benefit analysis carried out to show the balance between the risk benefit and the cost. The HSE provides guidance on use of CBA [10]. Care must be taken when evaluating risk in a qualitative or semi-quantitative way and using the analysis to show that the residual risk is ALARP as these techniques usually do not give a direct measurement of risk to which the costs of the measure can be compared.

It is important to note that that the decision is unlikely to be based on just one of these methods. In the first instance, any assessment will still need to take account of relevant good practice. In addition, a combination of deterministic engineering analysis and risk assessment will be required for this decision context.

To provide a simple example for an area in a facility:

- Explosion analysis provides the worst case explosion overpressures.
- Engineering analysis indicates that design to these pressures would be impracticable.
- A risk assessment is then conducted to determine the design that provides a protection that would at least reduce risks to a level that is ALARP.

In conducting a risk assessment, information may be drawn from a range of sources, including engineering analysis, generic industry data and operator specific data. In all cases, the process must be used in such a way that the decision can be made with sufficient confidence that the risks are at least reduced to a level that is ALARP.

The more uncertainty (or complexity) associated with the decision, the more likely it is that different (and more complex) techniques will be deployed to minimise the uncertainty.

In any assessment where more than one technique is used, if different techniques give different results, the results should not be assigned a weighting in order to arrive at a final decision[2]. If different outcomes arise from different techniques, this indicates that the assumptions and data used in the assessment should be re-examined, or the use of the techniques themselves questioned. Expert knowledge of the different assessment techniques is therefore required (see Section 6) and if significant uncertainties remain, then the precautionary principle needs to be invoked.

Cases 3, 4 and 5 in Appendix A in particular describe circumstances where a risk related decision is made by reference to a range of assessment techniques.

5.3.3 Precautionary Approach

If the assessment, taking account of all available engineering and scientific evidence, is insufficient, inconclusive or uncertain, then a precautionary approach to hazard management is needed. A precautionary approach will mean that uncertain analysis is replaced by conservative assumptions that will result in a safety measure being more likely to be implemented. The level to which this approach is adopted should be commensurate with the level of uncertainty in the assessment and the level of danger believed to be possible.

At greater levels of uncertainty, the precautionary principle is adopted.

Under the precautionary principle, the hazards that are assessed should at least include the worst-case scenario that can be realised, but should not include hypothetical hazards with no evidence that they may occur. While the approach adopted is expected to be proportionate and consistent, under the precautionary principle, safety is expected to take precedence over economic considerations, meaning that a safety measure is more likely to be implemented. In this decision context, the decision could have significant economic consequences to an organisation in conjunction with the safety implications.

The HSE's policy is that the precautionary principle should be invoked where [1]:

- *there is good reason, based on empirical evidence or plausible causal hypothesis, to believe that serious harm might occur, even if the likelihood of harm is remote; and*
- *the scientific information gathered at this stage of consequences and likelihood reveals such uncertainty that it is impossible to evaluate the conjectured outcomes with sufficient confidence to move to the next stages of the risk assessment process.*

[2] This is a change from the previous version of this guidance.

A precautionary approach may result in the implementation of risk reduction measures for which the cost may appear to be grossly disproportionate to the safety benefit gained. However, in these circumstances, the uncertainty associated with the risk assessment means that the risk associated with non-implementation cannot be shown to be ALARP with sufficient certainty.

5.4 Documenting a Decision

To provide auditability, and to facilitate future changes, communication to stakeholders and regulatory oversight, all risk related decisions should be recorded with justification for the options implemented and rejected.

6 Competence

Personnel using the framework must be competent in a number of areas in order to make a decision that is correct and robust. Such competence must cover:

- The installation and the procedures under which it operates;
- Technical aspects of the risk reduction measure(s) being considered; and
- Safety or environmental risk assessment, as necessary.

The decision process itself can be undertaken by risk professionals, although they should refer to the installation and subject matter experts as necessary and especially in relation to good practice. For them, competence means good knowledge of the risk assessment technique being used, the ways in which it can be used incorrectly and the limitations of the technique.

Appendix A - Examples of Application of the Framework

Case 1: Deluge on an Existing Platform

Scenario

On an existing un-manned installation, the water cut from wells has increased over time, the gas content of the production fluids has reduced and some equipment has been removed or decommissioned, whilst the deluge provision has never been changed. Significant time and effort is required to maintain the deluge system, parts of which are potentially no longer required.

Assessment

In this example, the potential risk reduction is one of reduced manning, although there is also the opportunity for manning to remain unchanged and improved maintenance to be carried out on areas of the system that are still required.

Codes such as NFPA define good practice for deluge requirements for different areas, but do not define the point at which the water cut means that the production fluids are no longer flammable (or beyond which deluge offers no benefit). Good practice also indicates that in areas where all the equipment is decommissioned and there is no fire risk, deluge is not required.

With the removal of elements of a key safety system, there was interest from oil company partners, the workforce and their employing company. This reinforced the need for a robust engineering risk assessment, using experimental results and careful consideration of all production scenarios including start-up.

The analysis showed that deluge was not required in some areas of the platform and can be decommissioned. The risk benefit of the deluge was shown to be minimal due to the lack of flammable inventory in the area being covered. The removal of the deluge was not considered to constitute reverse ALARP because the nature of the hazards had changed, meaning that application of good practice leads to different safeguards (deluge) than in the early years of production.

The decision context is B, with the decision supported by reference to good practice and engineering risk assessment.

Case 2: PSV Maintenance Intervals

Scenario

Pressure safety valves (PSVs) are used to protect a wide variety of equipment from over-pressurisation. The potential consequences on failure range from a significant loss of hydrocarbons to failure of an air line, whilst the failure rate between PSVs in different fluid service varies by almost a factor of 100. However, their maintenance (taking ashore, pre-popping, clean-up and replace of worn parts) requires significant effort and so there is therefore a need to determine a methodology to ensure that the PSV maintenance intervals are correctly assigned.

Assessment

The average individual risk is calculated in the platform QRA to be $2x10^{-4}$ per year. If the risk impact from any change to PSV maintenance intervals is small, the risk will still be in the ALARP region whereby it must be shown that further risk reduction (in this instance more frequent maintenance) is not reasonably practicable.

IP Model Code of Safe Practice for Pressure Vessels (Part 12) defines good practice for PSVs, but only at a high level, with maintenance intervals ranging from one year to six years, depending on the failure history of the PSV. While this provides a basis for further assessment, it is too coarse to allow a maintenance interval to be determined.

API RP 580/581 (Risk-Based Inspection) provides a risk-based methodology, but it is not tractable to implement for the many hundreds of PSVs found on an offshore platform.

Therefore, an engineering risk assessment methodology was developed such that for each PSV, a maximum maintenance interval was defined such that the quantitatively evaluated residual risk was below a company-defined risk limit. This risk limit corresponds to a justified spend that is very small (<£100) meaning that further risk reduction (more frequent maintenance) is not reasonably practicable. A qualitative assessment was then undertaken, so that if a PSV had poor or no operating history, its maintenance interval was lowered or not raised respectively. This latter aspect meant that good practice was met. The quantitative element is also used to show the risk actually drops with better targeted maintenance and so the ALARP approach is appropriate.

Beyond the operator, there is no stakeholder involvement in the decision process.

The decision context is borderline A/B, with the decision made by engineering risk assessment that is consistent with good practice.

Case 3: SSIV on a New Subsea Tieback

Scenario

A new subsea tie-back to an existing platform is planned. The well is located 8 km from the platform, which houses process and accommodation facilities. The production pipeline has a diameter of 6 inches and operates at 30 barg. The Duty Holder does not mandate the installation of SSIVs on all pipelines and so needs to make a decision on whether to install one.

Assessment

The individual risk is calculated in the platform QRA to be $3x10^{-4}$ per year. The additional individual risk from the new tieback with no SSIV is $4x10^{-5}$ per year, meaning that whatever the decision on the SSIV, the risk will still be in the ALARP region whereby it must be shown either that further risk reduction (the SSIV) is not reasonably practicable, or the measure implemented.

Good practice for such a situation does not clearly identify whether or not relatively short subsea tiebacks should have SSIVs installed. Examples exist in the North Sea both with and without SSIVs.

The well has a very low oil content, meaning that in the event of a release from the riser, oil pollution would be minimal. In addition, there is one similar riser on the platform with no SSIV. These facts mean that while partner and operator interest in the decision is high, there is no reason to take a precautionary approach and install the SSIV regardless of the analysis.

A consequence analysis shows that the flame length from a release from the riser can be significant, potentially initially reaching the underside of the TR and the nearby lifeboats. This indicates that a SSIV may have a consequence benefit. More detailed quantified risk assessment, taking account of the historical failure frequency of risers and the relatively short distance to the wellhead, on which the valves could be quickly closed in the event of an emergency, is then undertaken. This engineering risk assessment, combined with cost benefit analysis, shows that over the lifetime of the tieback it is reasonably practicable to install the SSIV. It is noted that the cost of replacement given failure during operations is high and so the SSIV is provided with a spare actuator.

The decision context is type B, with the decision made by engineering risk assessment with the chosen solution meeting relevant good practice.

Case 4: Decommissioning

Scenario

A producing platform that is also used to convey fluids from one asset to another is to be decommissioned. A decision on how to maintain flow between the other users once this installation has been decommissioned is required. Three main options are available:

1. A new pipeline bypassing the platform entirely;
2. A subsea bypass around the platform on the out-board side of the emergency shutdown valves (ESDV);
3. A topsides bypass inboard of the platform ESDV.

Assessment

All three options utilise well proven and well understood designs and technology. Option 2 has a challenge of requiring subsea intervention; however, this is a proven approach and not novel. Option 1 is by far the most expensive in terms of capital, Option 2 less so and Option 3 the least costly. Option 1 removes all hydrocarbons from within the 500m zone; Option 2 has residual pipeline inventories within the 500m zone and could impact decommissioning activities (Heavy Lifts etc.); Option 3 results in non-hydrocarbon-free topsides during decommissioning activities.

Stakeholder interests for these options are unlikely to be significant, although discussion with regulators (HSE and DECC) would be essential. Well established, understood and robust engineering and safety study techniques would be used to evaluate risk, both to people and the environment, and the cost implications associated with each in terms of methods for decommissioning. It is likely that the risk for all options would be in the 'ALARP region'.

The decision context is type B. Any solution will be designed to relevant codes and standards, but the decision will be made on which of the options reduces risks to ALARP taking into account not only the risks of installation, but also the lifetime risks and those associated with decommissioning activities. The risks must be balanced with the cost implications of decommissioning the asset with one of these three options in place.

Case 5: Degraded Caisson above a Subsea Pipeline

Scenario

Integrity issues were identified by an operator in relation to caissons under a gas production platform that had been operating for some 20 years. The issues related to both corrosion of the caissons and the potential for rapid fatigue failure as a result of wave motion effects following failure of caisson clamps.

One of these caissons, an open drains caisson, was located directly above the gas export pipeline from the facility. If the caisson failed and hit the pipeline, there was the potential to cause a loss of containment from the pipeline.

Assessment

Background

There were a number of factors that affected the risks associated with the caisson:

Factor	Comment
Caisson Integrity	The information on the integrity of the caisson was very limited, with no inspection data available for the main areas of concern on the caisson.
Previous History	The operator had experienced two full caisson failures within a set of twelve caissons within 20 years of facility operation (neither had had further consequences).
Sub Sea Isolation Valve (SSIV)	The SSIV fitted on the export pipeline at the time of construction was a flapper type check valve. It was not possible to proof test this valve for its ability to close, or to determine the passing rate if it did close.
Personnel on Board (POB)	The normal operations POB for the facility was 76, however, a maintenance campaign was planned with a Flotel alongside, raising the POB of the combined facility to 300. The plan was to have the platform in production for part of this period.
Background Risk	The QRA for the facility showed the most exposed personnel having an Individual Risk of 3.1×10^{-4} per year. This did not include any specific consideration of the hazard of caisson failure. The societal risks had also been calculated.

As well as complying with UK regulations for individual risk, the operator had also adopted a societal risk reporting criterion (shown in the FN plot in Figure A1 below). Although not required for regulatory compliance, the operator used this criterion to identify where risks should be reported to senior management, due to the potentially significant combination of safety, commercial and reputation risk. It should be noted that decisions made on the basis of meeting this criterion could lead to additional safeguards above those that would be required solely by a justification of risks being ALARP.

Decision Required and the Context

The decision required was a pressing need to determine the steps required to manage the risks associated with the caisson. The potentially severe consequences of gas pipeline failure under the facility and the poor understanding of the integrity of the caisson, meant that the additional risk from the caisson could be relatively high and even threaten tolerability limits. This indicated that the decision context was C, where a precautionary approach was likely to be required. The methodology adopted was:

- Conduct a preliminary engineering risk assessment to determine the threat the caisson presented to the pipeline, based on the limited integrity information available, the likelihood of the caisson striking the pipeline if it failed and the expected outcome if that strike occurred.
- Compare the total risk including that from the caisson with Individual and Societal Risk criteria.
- Determine immediate measures to be adopted for risk management.

- Define medium and long term risk reduction measures to be taken.

Results of Initial Engineering Risk Assessment

The integrity assessment had significant uncertainties and was unlikely to provide any reliable guide on the likelihood of failure. A dropped object analysis indicated that there was a 17% chance of the caisson striking the pipeline and that pipeline rupture was the expected outcome. Consequence assessment indicated that the whole facility, including the flare, would be engulfed in a flammable cloud. If the SSIV functioned, this position would last for a short period of the order of a minute. If the SSIV did not function, this would extend to a period of over an hour.

More Detailed Risk Assessment

There were clearly uncertainties within the data that could be used to assess the risks associated with the caisson failure. The approach taken was to assess the upper and lower limits to the input information and combine these to give an overall upper and lower limit to the risks. Given the unknown state of the SSIV, the risks were calculated separately for the case that the SSIV would function or would completely fail to operate.

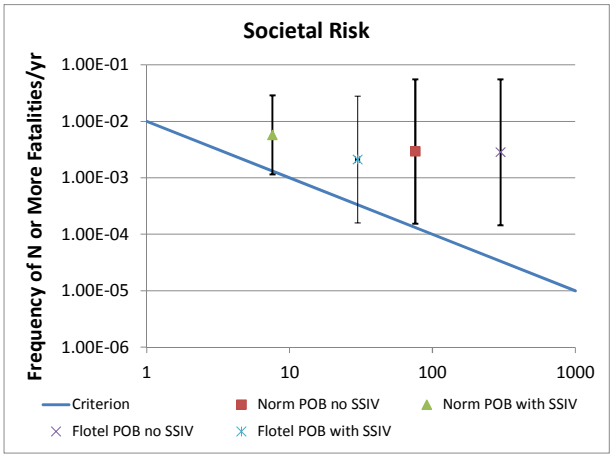
The upper and lower estimates for the input data are given in the table below.

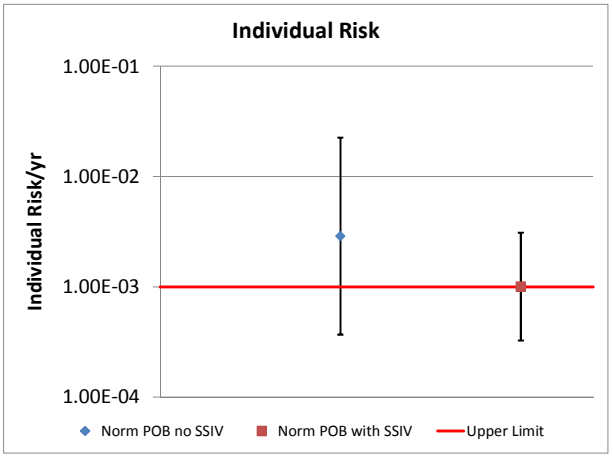
The results are plotted in Figure A1 below, with the mean value being the geometric mean between the upper and lower limits.

Element	Range	Value	Justification
Caisson Failure Rate/yr	Lower	8.3×10^{-3}	Based on two caisson failures from a population of 12 caissons over an operational period of 20 years and assuming a constant failure rate.
	Upper	5.6×10^{-2}	Assuming failure due to ageing and has only been possible in the last 3 years.
Caisson Impact Probability	Lower	0.17	Dropped object analyses normally assume that an object is dropped from above the water level and can enter the water at any angle. The caisson was already in the water and aligned vertically, directed at the pipeline. The assessment was therefore considered optimistic and the upper limit takes the precautionary approach of assuming impact in all cases.
	Upper	1	
Ignition Probability – SSIV functions	Lower	0.1	OGP published data on ignition probability given platform engulfment.
	Upper	0.5	Presence of flare and likelihood of engulfment, but there is a possibility that the wind direction may prevent ignition.
Ignition Probability – SSIV fails	Lower	0.1	OGP published data on ignition probability given platform engulfment.
	Upper	1	The long duration of the event and the presence of the flare makes ignition highly likely.
Proportion of time outside for most exposed personnel	All cases	0.25	Approximation for process worker group, used for calculating their individual risk.
Proportion of time offshore	All cases	0.4	Normal rotation pattern, used for individual risk only.
Fatality Rate given Ignition and SSIV Closes	All cases	0.1	Assumed all those outside are fatalities and that this approximates to 10% of personnel, used for societal risk.

Element	Range	Value	Justification
Fatality Rate given Ignition and SSIV Fails	All cases	1	The platform would be engulfed in a fire for over an hour, escape would be unlikely and collapse inevitable, used for societal risk.

Figure 2: Calculated Societal and Individual Risk





The graphs show different cases (SSIV operational or not, Flotel present or not) for particular numbers of fatalities and these can be compared to the criterion lines. It should be noted that the societal risk plot provides points that the societal risk curves for the four separate cases being considered would pass through; they do not represent four points on a single curve formed by joining the points together.

It can be seen that the individual risk was highly likely to be intolerable and that the societal risks were significantly above the reporting line, almost regardless of the uncertainty. On this basis, the operator took the precautionary approach and the platform was shut down.

The next stage was to evaluate under what conditions production could be re-instated. The initial stages of this were carried out in a workshop to define possible risk reduction measures. The primary elements to the restoration of production were:

- Inspection of the caisson condition as far as would be practicable to re-assess the potential for failure; this would include the existing guides and clamps.
- Installation of a restraint designed to prevent the caisson from falling if it failed.
- Implementation of frequent visual inspections of the restraint and caisson.
- Investigation of the SSIV state, given that the pipeline was depressurised. Unless confidence could be obtained that the flap was in the 'down' position, the precautionary assumption would be made that the SSIV was in a failed state.
- Recognising these as short to medium term solutions only, development of a plan for removal of the caisson and implementation of this as soon as practicable.

Given the mass of the caisson, protection of the pipeline was not practicable.

To assess the effect on risk, it was assumed that even given good inspection results and an engineered restraint, both the inspection and the restraint would have a 10% chance of failure. Being independent, they therefore provided two orders of magnitude reduction in risk, which effectively made the risks tolerable if ALARP for the individual risks and below the reporting line for the normal operations POB societal risk. However, the societal risks for the flotel case with the SSIV in a failed state would still

be above the reporting line. It was therefore important to gain some confidence in the condition of the SSIV to ensure that the Combined Operations could progress as planned.

Though some of the values used in this assessment could be disputed, their variation would be unlikely to have affected the decisions taken. Given the potential scale of the consequences, the operator took the precautionary approach in reducing the upper limits of the calculated risks to levels where they were not intolerable. The process had sufficient clarity to allow the basis of the decisions to be understood and the difficult decision to shut down justified. It also aided the definition of the conditions required for reinstatement of production.

Appendix B – References

1. Reducing risks, protecting people: HSE's decision-making process. UK Health & Safety Executive, 2001. http://www.hse.gov.uk/risk/theory/r2p2.pdf

2. Principles and guidelines to assist HSE in its judgements that duty-holders have reduced risk as low as reasonably practicable. UK Health & Safety Executive, December 2001. http://www.hse.gov.uk/risk/theory/alarp1.htm

3. Assessing compliance with the law in individual cases and the use of good practice. UK Health & Safety Executive, June 2003. http://www.hse.gov.uk/risk/theory/alarp2.htm

4. Policy and guidance on reducing risks as low as reasonably practicable in Design. UK Health & Safety Executive, June 2003. http://www.hse.gov.uk/risk/theory/alarp3.htm

5. Guidance on Risk Assessment for Offshore Installations. Offshore Information Sheet 3/2006, UK Health & Safety Executive. http://www.hse.gov.uk/offshore/sheet32006.pdf

6. ALARP Guidance – Part of the Petroleum Safety Framework, Commission for Energy Regulation (Ireland), CER/13/282 Version 2.0, November 2013. http://www.cer.ie/energy-safety/petroleum/alarp

7. Directive 2013/30/EU – Safety of offshore oil and gas operations and amending Directive 2004/35/EC, 12 June 2013. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:178:0066:0106:EN:PDF

8. Review of Hazard Identification Techniques. HSL/2005/58. http://www.hse.gov.uk/research/hsl_pdf/2005/hsl0558.pdf

9. Guidelines for Developing Quantitative Safety Risk Criteria, CCPS, 2009.

10. HSE principles for Cost Benefit Analysis (CBA) in support of ALARP decisions. UK Health & Safety Executive. http://www.hse.gov.uk/Risk/theory/alarpcba.htm