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What we can learn from ALARP regulation?

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Abstract

Potential hazards exist in almost all workplaces. The existence of these hazards can result in accidents or incidents that have an impact on people, equipment, materials, and the environment. To get the proper and good decisions regarding risks in the workplace, a risk level or risk priority is determined. The level of risk is used as a management tool in making a decision; therefore, the priority scale can be determined. In determining the priority problem, the ALARP (As Low As Reasonably Practicable) principle can be used.

Risk criteria are carried out as a basis for controlling hazards and making decisions to appropriate safety system to be used. The purposes of this thesis contain as the following; 1) Review relevant literature related to the ALARP regulation from various countries, 2) To study and analyze policy documents related to the ALARP regulation, 3) To investigate the understanding of the similarities and differences in ALARP regulation from one country to another. The use of ALARP in various countries prompted this thesis; General ALARP regulations from certain countries were selected as case studies and represent the regulations for the same industry.

Regulations from several countries have their own advantages and disadvantages, but the point is that the risk must be reduced to a level that is as low as reasonably practicable. The use of ALARP from the five countries, namely Norway, the United Kingdom, Denmark, Australia, and Singapore, the format of using the ALARP principle has a different approach across these countries will be interesting topics to discuss.

Keywords: ALARP, Cost-benefit analysis, Risk, Risk Acceptance Criteria

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Hopefully, this thesis can bring benefits to the development of science and technology in the future.

Stavanger, 15 Juny 2021

Chano Rinaldy Rivian

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List of Abbreviations

ALARP	As Low As Reasonably Practicable
ALARA	As Low As Reasonably Achievable
CBA	Cost-Benefit Analysis
HSE	Health, Safety, and Environment
LOR	Level of Risk
SFAIRP	So Far As Is Reasonably Practicable
SoS	System of System
TOR	Tolerability Of Risk
UK	United Kingdom

1 Introduction

1.1 Background

Everyone's safety standard is different. Some feel safe just driving without using a safety belt. But there are also those who immediately feel that something is wrong when they forget to wear a safety belt while driving. Likewise with companies. In the production process of oil and gas in particular, there are several unwanted adverse events that can threaten safety. If not handled properly, this incident can lead to the worst conditions that can threaten the safety of workers, damage equipment, and pollute the environment.

Therefore, in a company, especially an oil & gas company, there needs to be an agreement in setting work safety standards. Then, what are the bases used to reach the agreement? Generally, the company will refer to national and international standards. However, the debate often arises when determining the extent to which we must mitigate the risk of work accidents. In this case, companies in the world use ALARP. The ALARP Principle has two purposes for the HSE: it models the mechanism that risk designers should follow when assessing the tolerability of their expected risks, and it makes the mechanisms used by regulators in making evaluations clear. Tolerability of risk (TOR) system is what to refer to. (Redmill, 2010). Based on this statement, it is interesting to discuss the ALARP regulation from the perspective of various countries.

The ALARP principle, now widely applied to safety decision-making, requires that those responsible for workplace safety - and, indeed, public safety - should reduce risk to the 'As Low As Possible' level. The principle thus involves effective recognition of the fact that, although in many situations risk can be reduced, beyond a certain point, further risk reduction is increasingly expensive to implement (Jonas-Lee, 2011).

The as low as reasonably practical (ALARP) concept is a common risk management technique for what we called safety risks, risks that occur as a result of accidents. ALARP has proven to be a successful and widely used risk management approach, notably in Europe and the United Kingdom, where it has been defined in case law (Guikema, 2010).

The ALARP concept suggests both "reason" and "practicality" as a guide to regulatory decision-making. It implies that the technological and social perspectives on risk may be linked, as well as that society has a part in the decision-making process (Melchers, 2001).

There are a number of researchers who have studies related to this area. On the other hand, there is less study of the ALARP regulation from the perspective countries when we look into the difference and similarities between each country for the regulation in particular. Therefore, I will conduct the research and discuss the regulation review and will discuss furthermore.

This thesis will try to see from another point of view how the ALARP principle can be found in various countries. Several cases of the ALARP principle will be reviewed to see if there is a general pattern underlying to use of the regulation. The ALARP principle from each country summarized in the regulation report followed by the aspect of comparison in order to give options for inherent safety especially in the oil and gas industry. These topics will become the basis of the rationale for using the ALARP principle.

1.2 Objectives

The main objective of this thesis is to determine the differences and similarities in the regulation from a different country based on the literature review. In addition to giving insight into what is the appropriate regulatory practice and highlight the strengths and weaknesses that can be identified in each regulation. The government has the authority to determine and make decisions about public policies, and strategies, to suit its objectives. In addition, this study intends to explore the principle of ALARP in risk-based decision making. Therefore, this study will analyze and discuss data obtained from regulatory policy documents from several countries. The purpose of this thesis is to investigate, study, analyze, and compare the policy documents of a regulation. The following objectives described to fulfill the objectives of this thesis are:

1. Review relevant literature related to the ALARP regulation from various countries.
2. To study and analyze policy documents related to the ALARP regulation.
3. To investigate the understanding of the similarities and differences in ALARP regulation from one country to another.

1.3 Approach

Several ALARP regulations from several countries are selected and studied to analyze such as the compliance of the rules, differences in the rules, and what factors affect these rules. In order to understand the context of ALARP regulation, a detailed literature review from various sources, such as reports from the regulator and government references, will be used to investigate the use of ALARP regulation. The results of the literature review are then used to examine the ALARP regulations of several countries which are used to enable the prevention and mitigation of unexpected failures in the future. More detailed explanations will be presented in chapter 4.

1.4 Research Limitations

Several ALARP regulations from certain countries were selected as case studies and represent the regulations for the same industry. The main limitations are not every country uses the ALARP principle explicitly and the documentation of the ALARP principle is not really clear for a particular country. In addition, the ALARP rules in this thesis use references from the oil and gas industry. Other industries are not included in the discussion in detail such as the transportation or aviation sector. The regulation gathered from the government official webpage and some of the information is not specified in detail causes limitation on observation. Therefore, only regulations and associated policy documents which are available in an official English version are included in the review.

1.5 Report Structure

The thesis will be structured as follow:

- Chapter two will provide the basic knowledge about risk management in general. ALARP definition will be used as a foundation.
- Chapter three will discuss how to understand ALARP deeply. Various regulatory reports have different views on the application. The information from this chapter will serve as building blocks for the identification of regulatory patterns in later chapters.
- Chapter four will be mainly about the data and information source of this thesis.
- Chapter five describe on how ALARP regulation identified.
- Chapter six give suggested analysis chapter.
- The last chapter is the conclusions and recommendations for further work.

2 Background Theory

2.1 Introduction

This chapter is intended to give brief explanations regarding the basics of risk in general. A clear definition, as well as the current approach to manage risk, are provided. It is important to comprehend the concept of risk, as measures taken in line with the ALARP principle must prevent fatalities, personal injuries, or diseases in order to reduce risks (DWEA, 2017).

Further, a brief explanation about the concept of the cautionary and precautionary principles is also given in relation to the ALARP principle. It is also important to explain the concept of the cautionary and precautionary principles since the ALARP principle may be seen as a variant of the cautionary principle, which argues that in the face of uncertainty and risk, caution should be the ruling principle, such as refraining from engaging in an activity or taking steps to lessen risk and uncertainty (Aven, 2015). Furthermore, the next chapter will be explained the theory that supporting this thesis.

2.2 What is Risk?

In any field, of course there are risks that cannot be avoided, the risk will continue. Hence in principle, we inevitably have to face every risk from all the activities we carry out in our daily lives. However, that does not mean that the risk cannot be avoided, it cannot be minimized. In carrying out any activity, the risk will remain unavoidable. All that can be done is to minimize the possibility of the risks that arise. To be able to minimize the risks that may arise, whether in starting a business, conducting business cooperation, managing business expenditure budgets, and also other activities in daily life, we need to know well what is a risk.
Based on Oxford Dictionaries, the word *''Risk''* can be interpreted as (Aven, 2012);

> *(1) (Exposure to) the possibility of loss, damage, injury, or other adverse or unwelcome circumstance; a chance or situation involving such a possibility (2) A hazardous journey, undertaking, or course of action; a venture (3) A person or thing regarded as likely to produce a good or bad outcome in a particular respect; a person or thing regarded as a threat or source of danger. The risk concept is addressed in all fields, whether finance, safety engineering, health, transportation, security or supply chain management (Althaus, 2005).*

Risk conceptualization defined into two elements which are consequences (C) and uncertainty (U). The definitions (C, U) and (A, C, U) are equivalent for the risk term. C in (C, U) expresses all consequences of activities including event (A) (Aven, 2015). As a general description of the risk, we can write (C ', Q, K), where C’ is the specific consequences considered, Q is a measurement of uncertainty and K is the knowledge on which Q is based. The most common tool for describing the uncertainty of U is the probability P, but there are others including the probability (interval) that does not and representations based on evidence theory (belief function), likelihood and qualitative methods (Aven, 2012).

It is important to manage risks to prevent unwanted incidents from occurring. Different frameworks, standards, and books of risk management processes have been established to prevent various risks. All activities related to and managed by humans in all industries will lead to risk hence to prevent undesirable event the risk management is applied.

2.3 Risk Analysis

According to Häring, (2015) the definition of risk analysis is the determination of risks in a given context. The risk analysis process is an important part of risk management and has a basic structure which independent of its area of application (Aven, 2015). The main reason for conducting a risk analysis is to support decision-making. The analysis can serve as a useful tool for finding the right balance between various concerns, such as protection and cost (Aven, 2008). Figure 1 below shows the steps in the risk analysis process.

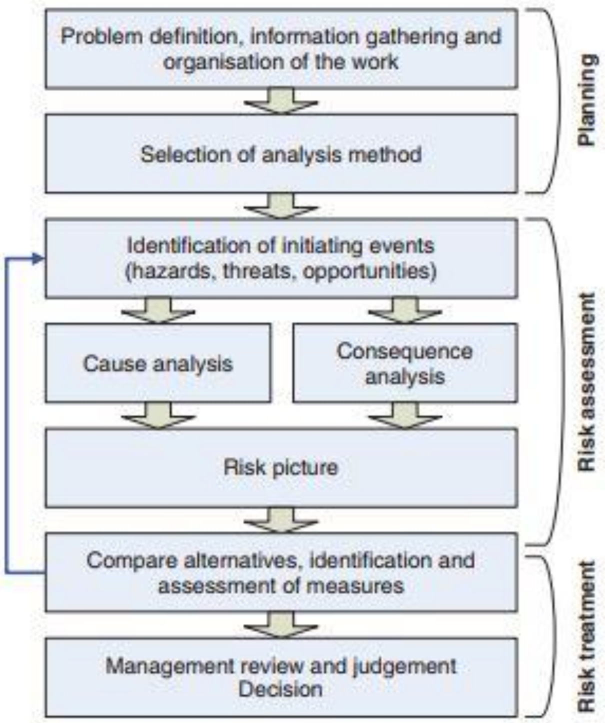


Figure 1 The main steps of the risk analysis process (Aven, 2015)

The aim of risk analysis is to understand the essence of risk and its characteristics, including the level of risk when necessary. Factors to consider in a risk analysis include (ISO, 2018); (1) the likelihood of events and their consequences; (2) the nature and magnitude of consequences; (3) complexity and connectivity; (3) time-related consideration and volatility; (4) the efficacy of existing controls; (5) sensitivity and confidence levels.
Below three differentiate main categories of risk analysis method such as simplified risk analysis, standard risk analysis and model-based risk analysis (Aven, 2008);

Table 1 Main categories of risk analysis methods (Aven, 2008)

Main category	Type of analysis	Description
Simplified risk analysis	Qualitative	Simplified risk analysis is an informal procedure that establishes the risk picture using brainstorming sessions and group discussions. The risk might be presented on a coarse scale, e.g. low, moderate or large, making no use of formalised risk analysis methods.

Standard risk analysis	Qualitative or quantitative	Standard risk analysis is a more formalised procedure in which recognised risk analysis methods are used, such as HAZOP and coarse risk analysis, to name a few. Risk matrices are often used to present the results.
Model-based risk analysis	Primarily quantitative	Model-based risk analysis makes use of techniques such as event tree analysis and fault tree analysis to calculate risk.

A risk analysis can be used to; (1) build a risk picture; (2) compare different alternatives and solutions in terms of risk; (3) define factors, circumstances, activities, systems, components, and other items that are essential (critical) in terms of risk; and (4) demonstrate the impact of various risk mitigation steps (Aven, 2008). Risk analysis gives the input to risk evaluation, as well as recommendations on when and how to handle risk, as well as the appropriate risk treatment approach and methods. The findings provide information for decision-making in situations where options include various types and levels of risk (ISO, 2018).

2.4 Risk Management

All companies and industries are very certain to face the unexpected situation, such as natural disasters, theft of funds, loss of staff and customers, and leakage of important documents. Each of these risks can harm the organization on a large scale. To anticipate unexpected situations, experts are needed to calculate these possibilities. Risk management is here as a solution to manage risks which every company facing. The main objective of implementing risk management concerned with resolving the tensions that arise from pursuing opportunities while also preventing damages, incidents, and disasters (Aven, 2007).

Risk management begins with a review of all relevant information, especially from a combined risk assessment, which consists of a risk assessment and a concern assessment where the latter is based on risk perception studies, economic impact assessments and scientific characterization of social responses to sources of risk (Aven, 2010). Risk management's central tenet is that it adds value to the company. To put it another way, risk management practices are intended to produce the best possible result while reducing volatility and uncertainty (Hopkin, 2018).

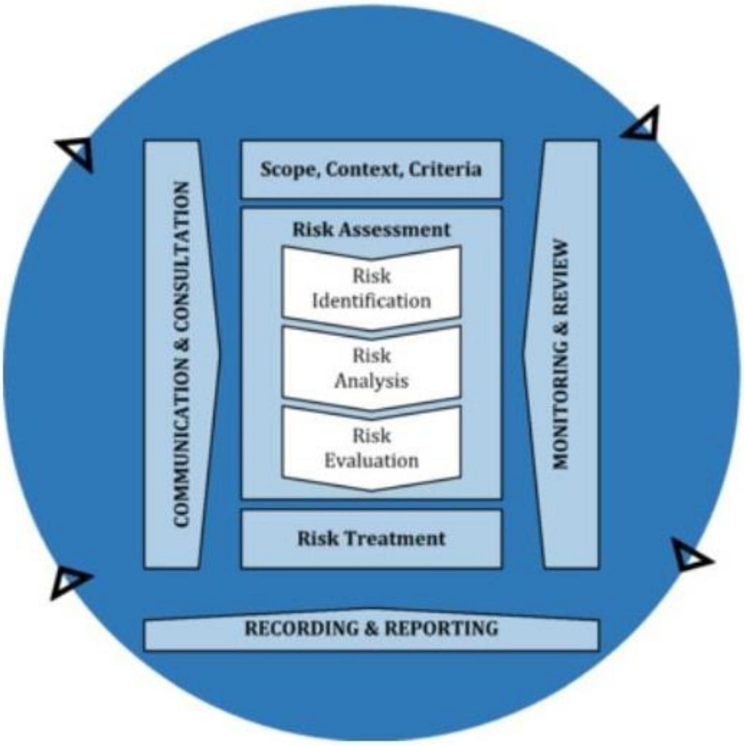


Figure 2 Risk management process (ISO 31000:2018)

There are a number of established risk management standards and frameworks, one example Figure 2 shows the main steps of the risk management process. A risk management standard sets out the overall approach for effective risk management, providing a description of the risk management process with a suggested framework that supports that process (Hopkin, 2018). This allows the company to establish procedures to avoid, minimize, and overcome the impact of unpredictable problems.

2.4.1 Risk Management Framework

The organization faces many challenges in achieving objectives and fulfilling role in society for economic development. With the revolution in information and communication technology, the emergence of a knowledge economy, economic instability and disruption, previously unexpected risks will emerge. Organizational ships need a skipper who is skilled to navigate this new sea with all the risks.

In order to be prepared for all risks, organizations need to develop a culture of risk awareness, where strong leadership is essential. Many organizations claim to include risk management in running their organizations, but do not let this be a mere statement. We need to integrate risk management in organizational governance, organizational activities and decision-making processes. Therefore, top leadership support is very important.

In a risk management framework, leadership and commitment are key, where without leadership and commitment to other frameworks it becomes difficult to carry out. The risk management framework illustrates the components of a framework Figure 3 which is divided into five main phases: integrating, designing, implementing, evaluating and improving risk management (ISO 31000:2018).

Figure 3 Risk management framework (ISO 31000:2018)

2.4.2 Benefit of Risk Management

Every business has faced unforeseen risks that could drain costs or cause it to close permanently. One concrete example is the Covid-19 pandemic which forced a number of businesses to go out of business because they did not have adequate preparation. This risk can actually be minimized through the application of risk management. Because risk management can help a company or organization prepare for the unexpected by minimizing additional risks and costs before the event takes place. The application of risk management and risk prediction can help companies save expenses while protecting the future. Because the right risk management plan will help the company establish procedures to avoid threats, minimize negative impacts, and overcome these threats.

Based on Hopkin (2018), The primary advantage of risk management is that it improves the efficacy and quality of an organization's operations. It can also assist in ensuring the effectiveness and efficiency of business processes (including process enhancement by tactics, programs, and other reform initiatives). The strategy chosen must also be effective and efficient, because it is able to provide exactly what is needed. Include risk management in its assessment by making decisions, but also in its appraisal with the effective implementation of projects and work programs, and in carrying it out with organizations. The benefits of risk management can also be identified in the organization by three timescales of activities within the organization. The outputs of risk management activities can benefit the organization on three scales and ensure that the organization achieves effective and efficient strategies, tactics, and operations.

2.5 Risk Acceptance Criteria

Based on Aven (2008) Risk acceptance criteria defined if the calculated risk is lower than the predetermined value, then the risk is acceptable (can be tolerated). Otherwise, the risk cannot be accepted (cannot be tolerated), and risk reduction measures are required. For example, the frequency of events during 1 year resulting in reduced safety functions must not exceed 1 x 10−4 (Aven, 2008). If the risk analysis arrives at a calculated frequency higher than this limit, then the risk cannot be accepted, and if the frequency is lower, then the risk is acceptable. Risk acceptance criteria adopted for rational and informed decision-making across all phases of resilience management. In particular, they can be used to decide whether the frequencies are desired or undesirable (probability) or should be increased or decreased, or decreased, respectively. In particular, different criteria can be used in different resistance.

It is common sense that the risk management process, and especially the ALARP process, requires formal guidelines or criteria (e.g., risk acceptance criteria and cost-effectiveness index) to simplify decision-making. However, caution should be exercised when using these types of formal decision-making criteria, as they easily result in mechanization of the decision-making process (Häring, 2015). Risk acceptance criteria are defined to differentiate between acceptable and unacceptable risks. Decisions about what is acceptable can be based on different principles. Three principles (equity, utility and technology) to motivate risk criteria are shown in Figure 4 below.

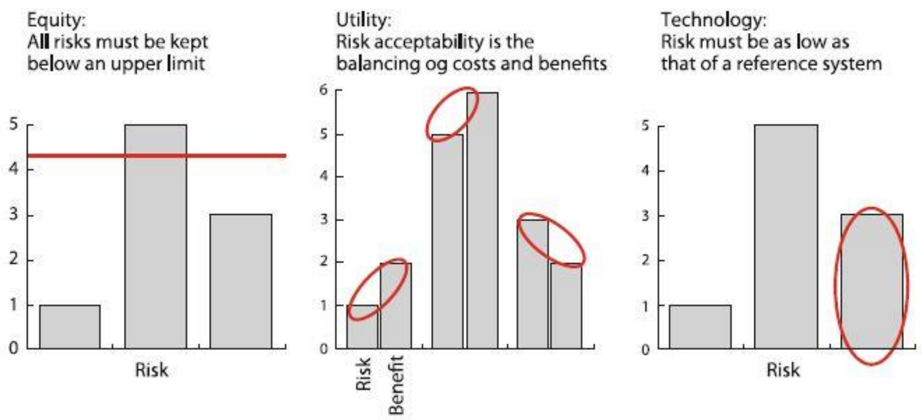


Figure 4 Three lines of reasoning as visualized by (Johansen, 2010)

2.6 Cautionary principle and precautionary principle

The cautionary principle is a fundamental principle in safety management, which states that in the face of uncertainty, caution should be a ruling principle (Abrahamsen, 2007). The cautionary principle is an essential risk management principle that is strongly related to the robustness and resilience of risk management strategies (Aven, 2019). The cautionary principle means that not starting an activity or by implementing measures to reduce risk and uncertainty, will be the main principle when there is uncertainty associated with the consequences, when there is a risk (HSE 2001, Aven and Vinnem. 2007). The ALARP principle gives the cautionary principle a strong amount of weight (Abrahamsen, 2007).

As it refers in situations of scientific uncertainty, the precautionary principle may be considered a special case of the cautionary principle (Aven, 2015). The term "precautionary principle" came into English as a translation of the German word Vorsorgeprinzip. An alternative translation might be "foresight principle" (Kriebel, 2001). Over the years, the precautionary principle has been one of the main principles for making decisions involving environmental protection and human safety. De Sadeleer (1999) argues that the precautionary principle is about uncertain risk, which he defines as a situation where there is a serious suspicion of danger, even though scientific evidence is lacking. The requirement of caution is science-based must be clearly distinguished from nonsense perspective, but in some circles, the idea remains that no action should be taken against a suspected hazard unless there is complete scientific evidence of its existence. The level of care taken must of course be balanced with other issues, such as cost. However, all industries will introduce some minimum requirements to protect people and the environment, these requirements can be considered justified by reference to the precautionary principle. The precautionary principle is usually expressed as a decision-making decision in environmental and health matters (Hansson, 2020).

2.7 Cost-Benefit Analysis

The cost-benefit analysis was originally created for the assessment of public policy problems, but it is now used in a variety of contexts, including the evaluation of project activities in firms. A value that represents the decision maker's benefits and costs, as well as the decision maker's willingness to pay, may be used in the same way (Aven, 2008).

A traditional cost-benefit analysis is a method of calculating a project's benefits and costs. The country's currency is the common scale for measuring benefits and costs. The most important concept in converting commodities to monetary values is to determine the maximum amount that society is willing to pay for the project (Abrahamsen, 2007).

Several steps in cost-benefit analysis, in support of decision-making on reducing risks ALARP are (Rushton, 2006);

- Posing practicable risk reduction measures;
- Assessing risk reduction (the simplest approach is to assume elimination);
- Assessing "cost" (simple approaches involve scaling factors, as with usual project costing);
- Choose values for avoided harms and evaluate "benefit";
- Choose a gross disproportion factor (rarely >10);
- Assist in making decisions

Cost-benefit analysis is something you should consider when verifying ALARP principle. The use of cost-benefit analysis to support decision-making on safety investments and risk-reduction measures is fundamental to safety management, as shown by the norm. The cost-benefit analyses mean assigning monetary values to all relevant attributes, such as costs, safety, and calculating the expected net present value, E[NPV], to summarize the output of an alternative (Abrahamsen, 2007).

3 ALARP Background

3.1 Introduction

This chapter will explain the theoretical background of the ALARP principle. This chapter will review the theoretical background underlying the ALARP principle and how it influences our understanding of this principle used in industry. Different reports or literature may discuss different aspects underlying the principle itself. This chapter focuses on a deeper understanding of ALARP regulation meanwhile in chapter 5 will be discussed about the analysis for ALARP regulation of selected countries.

3.2 What is ALARP?

The oil and gas industry are high-risk industry. A major accident is an event that is not desired and often unpredictable which can cause loss of property and casualties that occur in a job. The risks that occur in human work activities are related to the possibility of work accidents. Every accident does not just happen, but there are factors that cause it. If we can know these factors, then we can take steps to prevent or overcome these accidents. In the oil and gas industry and other industries, different requirements are set for risk and risk exposure. The risk must be controlled hence the risk is minimized, one way to implement it can be applied reasonably with the ALARP principle.

The ALARP principle originated in an English court case from 1949. The court held that, ". . .in every case, it is the risk that has to be weighed against the measures necessary to eliminate the risk. The greater the risk, no doubt, the less will be the weight to be given to the factor of cost'' (Baybutt, 2014).

According to UK HSE (2021) ALARP stands for ''as low as reasonably practicable''. Another word is also used, namely ''SFAIRP'' which stands for "so far as is reasonably practicable''. The term ALARA (as low as reasonably achievable) also used in the United States of America exclusively in the field of radiation protection (US NRC, 2021).

ALARP is used to assess the level of 'risk', whereas SFAIRP is used to assess the level of 'safety'. Despite minor inconsistencies between the two terms, (Munson, 1988) claims that they are synonymous in fact. However, the use of the word ALARP in the UK, rather than

ALARA, appears to mean that achievable entails the potential possibility of going lower, even though this has not been proven in any practice.

Based on (Abrahamsen, 2015) the ALARP principle expresses that the risk should be reduced to a level that is As Low As Reasonably Practicable. This means that a risk reducing measure should be implemented provided it cannot be demonstrated that the costs are grossly disproportionate to the benefits obtained.

Using the ALARP theory to make decisions essentially ‘’involves weighing a risk against the trouble, time, and money required to control it’’. This involves judgment deciding whether the introduction of risk reduction measures is grossly disproportionate to the benefit of risk reduction achieved. Risk can be managed in three different ways, each requiring different amounts of time, effort, and/or cost. Figure 5 depicts an example of the ALARP concept (Hurst, 2019):

Example (A) appears to be proportional to the amount of effort to reduce risk. In this case, the steps will be implemented because there is no big disproportionality. Example (B) is very disproportionate (too much) compared to the benefits derived from further reducing the risk. The proposed action may not be justified. Example (C) is significant and the comparative time, effort, and cost required to achieve this are much less. Hence, there are advantages of further risk reduction. Thus, further action may be required in this case to confirm the risk is ALARP (Hurst, 2019).

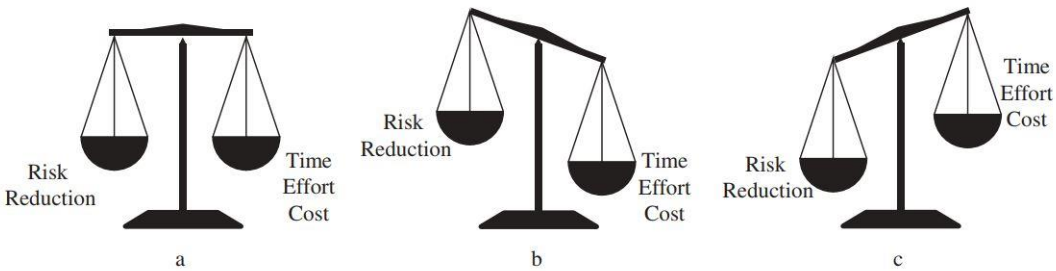


Figure 5 Illustration of ALARP thinking, with respect to the balance of risk (Hurst, 2019)

Is it assumed that the costs, time, and commitment must be ‘’proportional’’ to the risk reduction in order for ALARP to meet? (Jones-Lee, 2011) interpret ALARP to mean some imbalance in favor of risk reduction. To introduce an imbalance between costs and risks, ‘factors of disproportion' should be applied to the VPF (value of preventing a statistical fatality). The following factors are (Jones-Lee, 2011):

(i) low baseline individual risk and no societal risk, disproportion factors 1 and 2;

(ii) low baseline individual risk and societal risk applies, disproportion factor 3;

(iii) high baseline individual risk, disproportion factors 3–10 depending on the level of individual risk.

3.3 ALARP Framework

The ALARP risk decision-making framework is intended to reflect the types of safety decisions made in everyday life (HSE 1992, 2001b). This decision is based on the LoR (level of risk) and the level of public attention related to the particular technology, activity or situation that is being assessed (Clothier, 2013). One way for implementing ALARP such as;

1. Unacceptable, intolerable, or broadly unacceptable
2. Tolerable or requiring review
3. Acceptable or broadly acceptable
4. Negligible.

The ALARP theory implicitly acknowledges that in any company, zero risks are not an option. The ‘broadly appropriate' threshold is often used to denote the ‘safe' level in the sense of a safety risk. However, it should be noted that the risk threshold is not set at zero, and the risk is considered marginal rather than non-existent even at the point of the carrot in Figure 6 (Redmill, 2010). Below the ALARP risk framework presented.

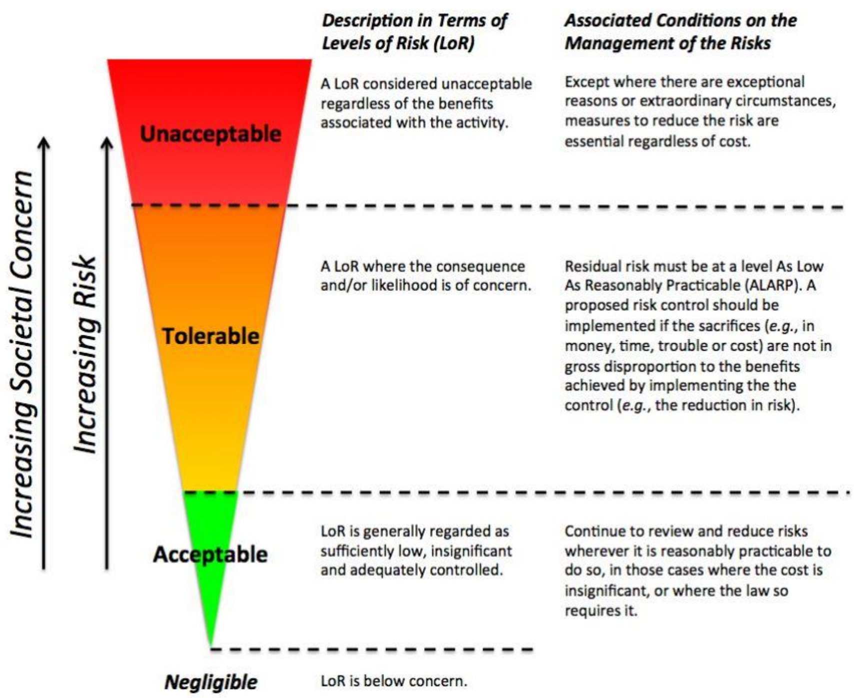


Figure 6 ALARP risk framework (Clothier, 2013)

In this way, verifying gross disproportion is an important part of the ALARP method. In general, methods focused primarily on engineering (good practice) judgments and codes are used, although more systematic decision-making techniques such as cost-benefit (cost-effectiveness) analysis are also used. Other alternatives, such as the layered approach, may be used to justify the judgments (Langdalen, 2020).

3.4 How ALARP should be implemented

Aven and Langdalen give recommendations on how it should be to implement the ALARP principle. Procedures based on engineering (good practice) judgments and codes are used in the verification of ALARP, although they are often followed by more systematic methods such as cost-benefit (cost-effectiveness) analysis. If the estimated cost is x times greater than the expected profit, the cost is deemed excessively disproportionate to the benefit in the cost-benefit analysis. Before the analysis, the decision-maker defines the value x, which is a disproportion criterion (factor). Regardless of the used cost-benefit (cost-effectiveness) analysis is commonly used to verify ALARP, it should be used with care since it is based on expected values (Langdalen, 2020).

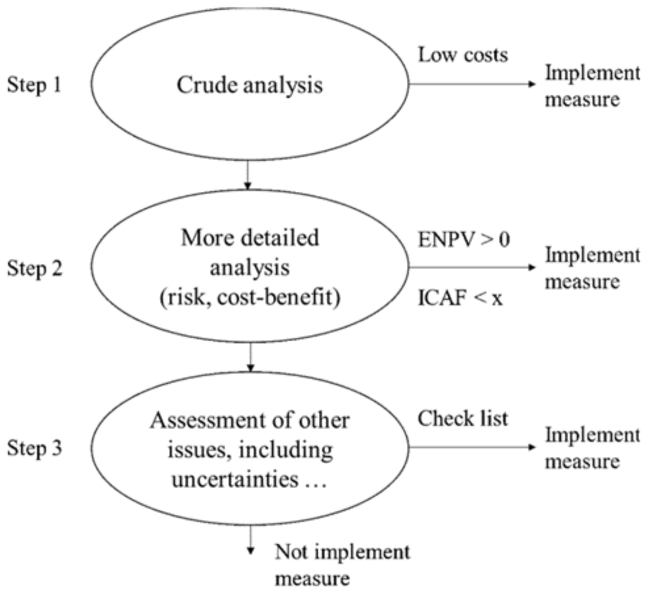


Figure 7 The layered approach for implementing ALARP and the gross disproportionate criterion (Langdalen, 2020)

To taking uncertainty into consideration account, Aven and Vinnem suggested the layered approach, which we refer to as an alternate method for demonstrating gross disproportion. As shown in Figure 7, the layered method consists of three measures (Langdalen, 2020).

3.5 Requirements for ALARP

To begin, any ALARP argument based on good practice enforcement should be investigated to see whether adequate good practice exists in all relevant areas to support the claim. This is especially true for SoS (System of system), where there may be a lack of existing good practice and where many of the confounding factors are more prevalent (including a lack of information transparency) (Menon, 2013).

Then, any argument that the system risk is ALARP should be accompanied by evidence that the system risk has been factored into individual risks. It is important to prevent both double-counting and risk omission. Furthermore, as we've seen, it's critical to figure out if factorization results in independent risks or risks that interact in any way (Menon, 2013).

After all, an ALARP statement must be legally backed by a search space justification; it must be shown that there is no reasonably possible way to reduce the risk further. If a different way to minimize the risk of ALARP is discovered, the optimal risk profile of the device must be considered (Menon, 2013).

3.6 ALARP regulation in the society point of view

ALARP decisions are often made in the context of equally dissimilar values, such as environmental, social, or community impacts, and are not often solved merely by comparing cost and safety (Stephens, 2016).

The precise tolerable probability levels that would qualify for approval by a regulatory authority are not always in the public domain, according to the ALARP approach's expositions. The applicant may not be aware of the tolerable risk criteria, necessitating some kind of negotiation between the regulatory authority and the applicant (Melchers, 2001).

It is important from a societal point of view to give more weight to safety which self-protection in particular. It is mentioned in (Abrahamsen, 2012) the authorities concerning what is necessary to define specific requirements have to be balancing by the authorities (since this may be considered as a conflict of the fundamental in internal control).

ALARP principle in its most basic form entails weighing the health and lives of the workers or the population in general alongside the wealth and livelihoods of the company's shareholders and employees (Stephens, 2016). Extending the ALARP balance to social and environmental values has introduced ramifications for other stakeholder groups, as seen in the table below.

Table 2 The ALARP balance to social and environmental values introduces impacts on other stakeholders groups (Stephens, 2016)

Value	Stakeholders	Obligations
Safety	Workers	To avoid physical harm
	Affected third parties	To avoid physical harm
Cost	Shareholders	To return a profit on investment
	Taxpayers	To provide services without excessive cost
	Employees	To ensure financial viability of business they depend on
	Consumers	To provide goods/services without excessive cost
	Suppliers	To ensure financial viability of business they depend on
Environment	Geographical neighbours	Not to damage ecosystems they depend on
	Future generations	Not to damage ecosystems they depend on
	Other species	To avoid physical harm
Community	Geographical neighbours	Not to damage social infrastructure
	Affected third parties	Not to cause financial or other losses etc.

The ALARP approach appears to enable a select group of people to make decisions about a potentially dangerous project away from public scrutiny and in consultation with the project's stakeholders (Melchers, 2001). According to (Stephens, 2016) four main characteristics proposed in the ALARP process focus on caring for neighbors, especially those who are most vulnerable; (1) It will be inclusive, identifying neighbors using systematic methods – all the stakeholder groups impacted by the operation – and ensuring that their impacts are considered (2) Rather than strictly financial terms, it will assess risks and benefits in terms of their effect on stakeholders' well-being. It could use money as a unit, but it would try to account for the different effects of a loss or gain on various groups (3) It would acknowledge that losses and gains have different impacts, and it would give greater weight to the impacts on the most vulnerable of these communities, including those who have the least control over the operation or are most impacted by it, as well as those who are disadvantaged or impoverished for other reasons. This is how, in the opinion, the disproportion element can be used to improve the weighting. This is how I suggest using the disproportion factor to increase the weighting of impacts on the vulnerable in comparison to more influential and resilient groups (4) It will be democratic, acknowledging that ALARP decisions have an impact on people's lives and livelihoods, and that they have the right to influence or at least have their interests considered.

Regarding (Clothier, 2013) the ALARP decision-making framework has an additional aspect which reflects social concern, as can be seen in Figure 6. The degree of "socio-political response" to the realization of a hazard is reflected in the societal concern dimension. Below are some of the characteristics that attract a higher degree of societal concern: 1). Lack of acquaintance with the potentially dangerous activity/technology 2). The magnitude of the negative consequences (e.g., multiple fatalities or widespread detriment) 3). Long-term consequences 4). Vulnerability of those affected by the hazard (e.g., children and the elderly) 5). Inequity in risk or benefit distribution linked with the activity 6). The exposure that is uninvited 7). Dreadful inspiration.

4 Data information and Method

4.1 Introduction

This chapter will elucidate the method based on literature study and review to interpret ALARP regulation from different countries. The data and information are based on reliable sources to support a deeper understanding for analysis. On the other hand, the review based on different and similar regulations such as; the term, the scope, legally binding, relation to risk acceptance criteria, to what extent does ALARP mean to use cost-benefit analysis? And the limitation. The detail of the review analysis will be presented in chapter 5. Below the selected countries will be analyzed in the process.

4.2 Data information

Data and information regarding the selected countries are obtained from ALARP regulation reports from a primary source of i). the regulation ii). associated regulatory authority reports. ALARP regulatory reports made by a government organization are built as the primary source of data and information because they have the most objective results since all activities carried out by the government have the best standards, which in the end generate positive values for the company. Basic search only on regulations and associated regulatory authority reports to ensuring objectivity topic.

Table 3 Source of data and information about the selected case studies

No.	Country	Source and Data Information
1.	Norway	1. Petroleum Safety Authority Norway (https://www.ptil.no/en) 2. NORSOK Standard (https://www.standard.no/)
2.	United Kingdom	1. HSE Gov UK (https://www.hse.gov.uk/) 2. Reducing risks, protecting people HSE UK Document (https://www.hse.gov.uk/managing/theory/r2p2.pdf)
3.	Denmark	1. Offshore olie-og gasaktiviteter Arbejdstilsynet (https://offshore.at.dk/) 2. Danish Working Environment Authority (https://at.dk/)
4.	Australia	1. National Offshore Petroleum Safety and Environmental Management Authority (https://www.nopsema.gov.au) 2. Department of Mines and Petroleum (https://www.dmp.wa.gov.au)
5.	Singapore	Ministry of Manpower (https://www.mom.gov.sg)

4.3 The review method

To analyze the data, a qualitative content analysis was conducted in a systematic and methodical review of several regulations for each country. This analysis method is aimed to describe inferences and interpretations on various characteristics of key regulations, the scope, What extent of the context in ALARP regulation, and so on. 5 countries were selected in this ALARP regulatory review, namely Norway, United Kingdom, Denmark, Australia, and Singapore. The reason for choosing those five countries is because most of them are in the oil and gas industry. Also, the regulations are available in English for the ALARP regulation in these countries. All collected data from government body regulations and the reviewed available publications were then used to study the hypothesis with comparison to the content analysis of policy documents, which will be thoroughly discussed in the following chapter.

5 ALARP Regulation Identification

5.1 Introduction

This chapter addresses the regulations and standards that are relevant to the ALARP principle and the risk aspect, in addition to how it is practiced in several countries. The regulations and standards, together with internal requirements and international standards form the limit of what is risk acceptable.

5.2 Selection of case studies

Several cases of the ALARP principle will be reviewed to see if there is a general pattern underlying the use of these rules. Different ways of interpreting the ALARP principle from several countries in the regulation aspect require a reduction in risk. Five countries were selected as a discussion topic where the ALARP principle was implemented and applicable to these countries. Below are five countries that are representatives to discuss ALARP regulations, such as Norway, United Kingdom, Denmark, Australia, and Singapore.

5.3 List of Attributes

In these summary tables, the ALARP regulation is assumed to contain: the term of ALARP for each country, the scope of regulation, legally binding regarding ALARP regulation, ALARP principle in relation to risk acceptance criteria, and to what extent does ALARP mean to use cost-benefit analysis, and the limitation of ALARP regulation itself. The list of attributes presented in table 5.1 below.

Table 4 List of attributes

	Norway	United Kingdom	Denmark	Australia	Singapore
The Term	Not Explicitly called ALARP/ALARA/SFARP	ALARP	ALARA/ALARP	ALARP	ALARP
The Scope	Onshore and offshore. These regulations do not apply to Svalbard	Offshore installations or in connected activities	Generally applied for regulation offshore, but special conditions offshore	Offshore Petroleum and Greenhouse Gas Storage	Persons/facilities/process at offshore petroleum facilities
Legally Binding	Yes	Yes	Yes	Yes	Yes
Relation to Risk Acceptance Criteria	In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved.	122 The dark zone at the top represents an unacceptable region. 123 The light zone at the bottom, on the other hand, represents a broadly acceptable region	Established quantitative limit for the highest acceptable level of risk	Risk is most commonly represented on an inverted triangle as increasing from a 'broadly acceptable' risk region, through a 'tolerable' region only if shown to be ALARP, to an 'intolerable' region, in which the risk cannot be justified on any grounds	By establishing a single scenario risk target, MHIs will be able to evaluate the risk of each SCE and determine, through the implementation of adequate and robust barriers, whether the risk is reduced to ALARP.
To what extent does ALARP mean to use cost-benefit analysis?	(1) Determine the optimum level of safety protection (2) Determine what is acceptable risk level (3) Determine the optimum level of emergency preparedness	Cost-Benefit Analysis aids the decision-making process	The assessment of costs of risk reduction measures includes both direct costs and indirect costs	The quality of the modelling and the data will affect the robustness of the numerical estimate	CBA may be used

5.4 ALARP principle in Norway

5.4.1 Petroleum Safety Authority (PSA) Norway

Petroleum Safety Authority Norway or Petroleumstilsynet in Norwegian is the government supervisory authority under the Norwegian Ministry of Labor and Social Inclusion. PSA has regulatory responsibilities for safety, emergency preparedness, and the work environment in the petroleum industry activities in Norway for both onshore and offshore. PSA's supervisory responsibilities cover petroleum activities across the Norwegian continental shelf, and onshore petroleum facilities and associated piping systems. Responsibilities include operating companies, rights holders, contractors, and owners, and covering all business phases - from exploration drilling, development, and operations to closure and removal (PSA Norway, 2020).

5.4.2 The Term

The term ALARP is actually not used in Norwegian petroleum regulations. In addition, not Explicitly called ALARP/ALARA/SFARP. The Petroleum Safety Authority (PSA) Norway regulation on § 11 Risk reduction principles stated that:

> *‘’In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved’’*

According to the above statement, it is in accordance with the concept of the ALARP principle, but it is not explained in detail or clearly that it is the term of the ALARP principle.

5.4.3 The Scope

In this section, the regulation divided into three aspects were applicable to the petroleum activities at onshore facilities (according to cf. Section 6 litera g), other activities at onshore facilities, according to (cf. Section 6 litera e) and apply to offshore petroleum activities according to (Chapters VI, VII and VIII on the regulation). In the first section, according to (cf. Section 6 litera g) stated that;

''The term petroleum activities does not cover onshore facilities for utilisation of petroleum that are not necessary for or constitute an integral part of production or transport of petroleum''

For example, gas power plants supply energy to grids or land-based industrial activities, and crude oil refineries where the petroleum obtained can be sent for processing to these, or other refineries fall outside the definition of petroleum activities. In the second section for other activities at onshore facilities, according to (cf. Section 6 litera e) stated;

''The term ''onshore facility'' is used as a collective term for onshore petroleum facilities covered by these regulations and supplementary regulations. The term includes both onshore facilities covered by the Petroleum Act and onshore facilities that fall outside the scope of the Petroleum Act''

The regulations also encompass the actual facility for production and/or utilization of petroleum and systems, installations and activities linked with the onshore facility or that have a natural connection to it, and encompass additional systems, facilities, and activities utilized for industrial purposes inside the ''fence'' of the relevant onshore facilities.

In the third section which apply to offshore petroleum activities, according to Chapters VI, VII and VIII on the regulation. In Chapters VI (Special offshore provisions according to the working environment act (§§ 33 - 44)) many aspects explained such as Minimum age, Ordinary working hours, Plans for working hours schemes and offshore periods, Off-duty periods, Breaks time, Overtime, Night work, and Work on Sundays. One highlighted on § 33 Multiple employers at the same workplace, principal undertaking in this chapter is

''The operator is the principal undertaking, second subsection of the Working Environment Act. However, the operator and the party responsible for the operation of a facility or a manned underwater operation that is carried out from vessels or facilities, can agree upon which of them is considered to be the principal undertaking''

Meanwhile, in chapter VII (Design and outfitting of facilities and conducting activities in the offshore petroleum activities (§§ 45 - 50)), several points are explained as follow: Development concepts, Oceanography, meteorology and earthquake data, Placement of facilities, choice of routes, Duty to monitor the external environment, Use of facilities, Safety work in the event of industrial disputes. One significant from this chapter is

> *''The design, engineering and construction of the individual facilities in a development concept shall allow them to be placed, operated and, if applicable, removed in a prudent manner. The same applies to installations and other equipment necessary to carry out manned underwater operations from a vessel''*

And it is also stated that;

> *''Facilities, including wells, shall be placed at a safe distance from other facilities and objects such as lighthouses, beacons, cables, pipelines and particularly vulnerable environmental values and the like, so that they will not constitute an unacceptable risk to other facilities, other activities or the external environment''*

While Chapter VIII (Offshore safety zones (§§ 51 - 61)) mentioned several in relation to Relationship to international law, Establishment of safety zones, Establishment of safety zones for subsea facilities, Temporary exclusion and hazard area, Requirement for impact assessments, etc., Cancellation of safety zones, Monitoring of safety zones, Warning and notification in connection with entry into safety zones, Measures relating to intruding vessels or objects, and Marking of safety zones. It is an essential part from this chapter shown.

> *''There shall be a safety zone around and above facilities, except subsea facilities, pipelines and cables, unless otherwise determined by the Ministry of Labour and Social Affairs''*

Each regulation applied for different of areal working such as onshore and offshore in general. These regulations do not apply to the Svalbard area.

5.4.4 Legally Binding

In relation to the legally binding, it is shown that the regulation on § 6 Definitions as stated on Licensee part:

> *''Physical person or body corporate, or several such persons or bodies corporate, holding a licence according to the Petroleum Act or previous legislation to carry out exploration, production, transportation or utilisation activities. If a licence has been granted to several such persons jointly, the term*

licensee may comprise the licences collectively as well as the individual licensee''

In addition, it is also related to the requirements associated with the license where;

''None other than the State may conduct petroleum activities without the licences, approvals and consents required pursuant to this Act. Provisions otherwise in the Act and regulations issued pursuant to the Act shall apply to such activities insofar as they are appropriate''

5.4.5 Relation to Risk Acceptance Criteria

In regulation Framework HSE section §11 risk reduction principles mentioned that;

In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved.

In reducing the risk, the responsible party, for instance, operator/company, shall choose the technical, operational, or organizational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved. Furthermore, the following regulation in the management regulations number §9 acceptance criteria for major accident risk and environmental risk stated;

a) the personnel on the offshore or onshore facility as a whole, and for personnel groups exposed to particular risk,
b) loss of main safety functions for offshore petroleum activities,
c) acute pollution from the offshore or onshore facility,
d) damage to third party.

Acceptance criteria for the major accident and the risk to the environment which the operator and the entity in charge of managing a mobile facility must establish acceptability criteria for major accident risk and environmental risk related to acute pollution. Acceptance criteria must be established, such as above. When evaluating risk analysis results, the acceptance criteria must be applied.

5.4.6 To what extent does ALARP mean to use cost-benefit analysis?

There are at least three types of cost-benefit analysis purposes according to E.1 Purpose of Cost-Benefit Analysis in the regulation based on NORSOK Standard Norway. The general purpose of Cost-benefit analysis shown in the regulation, as can be seen below;

> • *Determine optimum level of safety protection when risk acceptance criteria have been satisfied through prior risk assessment. Usually this will imply that risk acceptance criteria for personnel (possibly also environment) have been satisfied, and that the CBA is used in order to find the optimum level of protection against material damage risk. (Type I).*

Firstly, type I, the cost-benefit used as the optimum level of protection. 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 further enhancement of safety in the activities become a dynamic and forward-looking process (Aven, 2006).

> • *Determine what is acceptable risk level without prior satisfaction of risk acceptance criteria. If this is the case, usually the same approach is then applied to risk to personnel, risk to environment and risk to assets, which all then are evaluated within an ALARP context. (Type II).*

Secondly, in type II, accidents must be avoided at all costs (any actual accidental event is unacceptable). This means that risk is kept as low as reasonably practical (ALARP), with efforts are made to reduce risk over time. The requirement for risk mitigation measures is determined using the acceptance criteria. The acceptance criteria, as well as the reasoning behind them, must be documented and auditable (Aven, 2006).

> • *Determine optimum level of emergency preparedness when risk acceptance criteria and functional requirements to emergency preparedness have been satisfied through prior risk assessment and emergency preparedness analysis. (Type III).*

Thirdly, type III, all technical, operational, and organizational measures that prevent a dangerous situation from becoming an unintentional event or avoid or mitigate the adverse impacts of accidental events that have occurred are considered emergency preparedness (Sommer, 2018).

5.5 ALARP principle in the UK

5.5.1 The Health and Safety Executive (HSE) UK

The Health and Safety Executive (HSE) is the UK government agency responsible for the encouragement, regulation, and enforcement of workplace health, safety, and welfare and for occupational risk research in the United Kingdom. HSE UK is sponsored by the Department of Work and Pensions. As part of duties, HSE UK investigates several cases such as industrial accidents, small and large incidents (including major incidents such as explosions and fires) (HSE UK, 2021).

5.5.2 The Term

The term ALARP has been used in the United Kingdom; according to Ale (2015), the origins of the term ALARP may be established introduced in the United Kingdom, and it actually predates the term ALAP (As Low As Practicable). Between the late 1960s and the late 1980s, the term ALARP appears to have emerged in relation to how the UK Health and Safety Executive dealt with risk from nuclear power plants. In addition, following the recommendations made in the Robens Report on Safety and Health at Work in 1972, the Health and Safety at Work (etc.) Act 1974 (HSWA) defines the ALARP principle as a regulatory requirement (Jones-Lee, 2011).

5.5.3 The Scope

The scope of the ALARP principle in the United Kingdom mainly focuses on offshore installations or connected activities. One interesting subject in relation to connected activities can be obtained from regulation number 114. The following are some examples of connected activities that should be considered in safety cases;

> *''(a) supply vessels delivering goods or materials whether by crane hoist or directly into the installation's bulk storage system; (b) diving activities undertaken from a diving support vessel alongside the installation; (c) loading vessels to transport hydrocarbons from storage on the installation to shore terminals; (d) heavy lifts undertaken from a heavy lift vessel alongside the installation; and (e) work by service vessels on sub-sea wells connected to the installation''*

Production process facilities must be properly designed to work safely, following the appropriate technical rules. If all safety equipment from each part of the process is combined into a production facility, there will be no new safety threats; therefore, all process equipment is logically integrated into the safety system, hence that all facilities are protected.

5.5.4 Legally Binding

According to regulation in relation to legally binding where;

> *''the general provisions of the HSW Act and associated regulations such as the Management of Health and Safety at Work Regulations 1999 (SI 1999/3242) (MHSWR) and the Provision and Use of Work Equipment Regulations 1998 (SI 1998/2306) (PUWER) apply to all offshore employers, including those who are also duty holders under OSCR and the other offshore-specific regulations''*

In general, the above regulations require that what companies do to manage health and safety in the workplace under the health and safety work act. Work act defines general tasks assigned by the company to employees and the surrounding environment for various work activities.

Furthermore, based on (HSE, a short guide) it is explained that Employers are required to conduct risk assessments, make arrangements to implement necessary measures, appoint competent individuals, and provide appropriate information and training under the Management of Health and Safety at Work Regulations 1999. Meanwhile, The Provision and Use of Work Equipment Regulations of 1998 require that all work equipment, including machinery, must be safe.

5.5.5 Relation to Risk Acceptance Criteria

Concerning risk acceptance criteria, the figure presented in the regulation, HSE framework for the tolerability of risk proposed three-zone to represent the level of risk, as below;

In regulation number 122 stated that on the top of the figure framework is;

> *The dark zone at the top represents an unacceptable region. For practical purposes, a particular risk falling into that region is regarded as unacceptable whatever the level of benefits associated with the activity.*

It means everything in the dark zone that occur risk will be ruled out. Further, in the middle of the figure described as the tolerable region as the regulation stated on number 124:

> *124 The zone between the unacceptable and broadly acceptable regions is the tolerable region. Risks in that region are typical of the risks from activities that people are prepared to tolerate in order to secure benefits*

Furthermore, the bottom in the figure considered as a broadly acceptable region:

> *123 The light zone at the bottom, on the other hand, represents a broadly acceptable region. Risks falling into this region are generally regarded as insignificant and adequately controlled.*

Meanwhile, in the lower limit zone, the regulation basically does not give any special circumstances. This zone is basically considered a safe zone from the regulation. Further explanation about the HSE framework figure will be explained in the discussion chapter.

5.5.6 To what extent does ALARP mean to use cost-benefit analysis?

Retrieved from HSE principles for cost-benefit analysis (CBA) United Kingdom which presented below;

> *''Cost-Benefit Analysis aids the decision-making process by giving monetary values to the costs and benefits and to enable a comparison of like quantities. The analysis can help make an informed choice between risk reduction options. A Cost-Benefit Analysis cannot form the sole argument of an ALARP decision nor can it be used to undermine existing standards and good practice''*

It is a similar statement as (Abrahamsen, 2007) the use of cost-benefit analyses to support decision-making on safety investments and risk-reduction measures are fundamental to safety management, for example, the standard. In addition, cost-benefit analyses entail assigning monetary values to all relevant attributes, such as costs and safety, and calculating the expected net present value, E[NPV], to summarize the performance of an alternative.

5.6 ALARP principle in Denmark

5.6.1 The Danish Work Environment Authority

The Danish Work Environment Authority or Offshore olie-og gasaktiviteter Arbejdstilsynet in Danish is the Denmark authority in the field of the work environment.

The mission is to promote a safe, healthy and thriving work environment and prevent friction, sickness absences, and exclusion from the labor market (Danish WEA, 2013).

5.6.2 The Term

The term ALARP or ALARA has been used in this regulation. The regulation views ALARA and ALARP as synonyms. The term of ALARA in environment project 112 clearly stated in one subject that;

> *Societal risk formulated as a risk of death of 10-4 per year for an accident involving at least one fatality. Where societal risk falls within the shaded grey region above the minimum curve, the risk should be "As Low As Reasonably Achievable" (ALARA).*

And also, the ALARP term has been found in many subjects. The term of ALARP stated on 1.6 ALARP demonstration in particular;

> *''Demonstration that risks have been reduced in accordance with the ALARP principle, including that good practice has been used, when available; and including a description of cases in which risks have not been further reduced and the reason why there is a gross disproportion between costs and risk reduction''*

In line with Aven (2015) the risk should be reduced to a level that is as low as reasonably practicable (ALARP); it means that the benefit of a measure should be considered in proportion to the disadvantages or costs of the measure.

5.6.3 The Scope

The regulation stated that the main principles of the Offshore Safety Act as below;

> *''That the level must correspond to the level onshore means that the regulations according to the Working Environment Act are generally applied for regulation offshore, but special conditions offshore, both technical conditions and, with respect to mobile installations, international conditions, are also taken into account''*

As we can see above, the scope of regulation mainly for offshore and onshore in respectively. Further, the regulation also mentioned that:

''In order to ensure that the players, i.e. the enterprises, manage health and safety risks and risks of major environmental incidents in accordance with the Act, or regulations pursuant to the Act, they must establish a management system for health and safety. The health and safety risks and risks of major environmental incidents must be brought to a level which is as low as reasonably practicable (ALARP)''

The Act's goal is to promote a high level of health and safety that is in line with technological and social advances in society. That is at least equal to the onshore level, adapted to the special conditions offshore. The use of the ALARP principle is one of the important factors to eliminate or reduce this risk, as well as supervision by the authorities especially aimed at the company's management system.

5.6.4 Legally Binding

It can be obtained from the Danish Working Environment Authority, in regulation the meaning of licensee is;

''The enterprise or group of enterprises which, pursuant to the Danish Subsoil Act, is authorised to carry out offshore oil and gas operations''

Looking at the meaning of licensee, the regulation on part 4.3 Licensee gave a specific subject which;

"The enterprise or group of enterprises which, pursuant to the Danish Subsoil Act, is authorised to carry out offshore oil and gas operations"

In addition, for instance;

The "Sole Concession of 8 July 1962" has a special status. The concession is held by A. P. Møller-Mærsk A/S and Mærsk Olie og Gas A/S, referred to as the "concession holders". The duties and responsibilities of the concessions holders are the same as those of the licensees.

As resulted from above, the licensee under Danish subsoil act, the regulation started from the "Sole Concession of 8 July 1962 to A. P. Møller-Mærsk A/S and Mærsk Olie og Gas A/S as stepstone oil and gas industry in Denmark. On the other hand, based on (Oxford dictionary) the definition of concessions is a right or an advantage that is given to a group of people, an organization, etc., especially by a government or an employer.

In addition, the regulation also mentioned that;

> *The ALARP principle is an internationally recognised principle used in the offshore oil and gas sector. Application of the ALARP principle in the Offshore Safety Act corresponds to the principle in the Working Environment Act that health and safety conditions must be fully justifiable, taking social and technological societal developments into consideration.*

5.6.5 Relation to Risk Acceptance Criteria

The risk levels are illustrated by the ALARP triangle presented in the regulation. In relation to risk acceptance criteria, the regulation says;

> *Established quantitative (measurable) limit for the highest acceptable level of risk to perform an activity under normal operating conditions. The acceptance criteria are limits for when an activity may be carried out.*

In the regulation ALARP triangle divided into three areas as described below;

> *a highest acceptable level of risk and a generally acceptable level of risk must be established. The region between these levels is known as the ALARP region or the acceptable (or tolerable) risk.*

The regulation also pointed out where the operator and the owner, respectively, shall develop acceptance requirements for significant accident risks, while the operator and the owner, respectively, develop acceptance criteria for other health and safety risks in line with their respective health and safety management systems.

Indicating from the regulation on 3. Identification of any additional risk reduction measures that can be implemented physically or operationally can be seen;

> *(a) The measures can be implemented, unless it can be demonstrated that this is not reasonably practicable.*
> *(b) If the benefits of a risk reduction measure cannot be assessed with sufficient accuracy to determine whether it is reasonably practicable to implement the measure, the precautionary principle must be applied.*

In accordance with Kauer (2002) there are three qualitative definitions of the risk acceptability limit in following below; (1) There should be no risks associated with industrial activity that can be reasonably avoided (2) The costs of avoiding risks should not be disproportionate compared to the benefits (3) Catastrophic accident risks should be a modest percentage of the total.

5.6.6 To what extent does ALARP mean to use cost-benefit analysis?

In relation to the cost-benefit analysis, in part 4.1.1 ALARP give some demonstration for risks of major accidents in relation to cost aspect;

> *The justification must include information about the costs associated with establishing risk reduction measures, and an assessment of whether these costs are grossly disproportionate to the benefits gained by the risk reduction. Where the costs are grossly disproportionate to the additional risk reduction achieved by means of the risk reduction measures, the risk reduction measures may be omitted, provided that good practice has been followed and appropriately documented.*

It is important to reducing exposure to hazards, minimizing risks with proper management, and increasing preparedness for impacts on risks.

But regarding the cost aspect in chapter 3.5. explained that the cost analysis issue is described in more detail on the British Health and Safety Executive's website. Therefore, the regulations in Denmark also use a lot of regulatory principles in the United Kingdom.

5.7 ALARP principle in Australia

5.7.1 National Offshore Petroleum Safety and Environmental Management Authority

National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) is Australia's independent expert regulator for health and safety, structural integrity for wells, and environmental management for all oil operations as well as offshore gas and greenhouse gas storage activities in Commonwealth waters and in coastal waters where regulatory powers and functions have been assigned. NOPSEMA was established on 1 January 2012, superseding the National Offshore Petroleum Safety Authority (NOPSA) (NOPSEMA Australia, 2013).

5.7.2 The Term

Displaying from the regulation objects where on point (3) and (6), which documented as;

> *(3) An object of these Regulations is to ensure that the risks to the health and safety of persons at facilities are reduced to a level that is as low as reasonably practicable*
>
> *(6) An object of these Regulations is to ensure that the risks to the health and safety of persons who carry out diving to which the Act relates are reduced to a level that is as low as reasonably practicable.*

That is obvious the ALARP principle mentioned in the sentence as low as reasonably practicable. The term ALARP becomes the highlighted point, not ALARA, neither SFARP.

5.7.3 The Scope

The scope covered in Offshore Petroleum and Greenhouse Gas Storage (Safety) as mentioned on guideline document no N-01000-GL0253 A15295 part 3.1 Facility, installations defined within the scope into two subjects (1) and (2);

> *(1) Other activities that cause vessels or structures to be facilities include activity categories covered in subclause 4(1)(b)(ii) - (vi), and include:*
>
> *• accommodation for persons working on another facility*
>
> *• drilling or servicing a well for petroleum or work associated with drilling or servicing*
>
> *• laying pipes for petroleum, including any manufacturing of such pipes, or for doing work on an existing pipe*
>
> *• erection, dismantling or decommissioning of a facility.*
>
> *(2) Categories of activities cause relevant vessels or structures to be defined as facilities and the Clause 4 definition lists these activities. Sub-clause 4(6) lists the following that are not facilities:*
>
> *• off-take tankers*
>
> *• tugs or anchor handling vessels*
>
> *• vessels used for supplying facilities or for travelling to or from a facility*
>
> *• any vessel or structure declared by regulations not to be a facility.*

5.7.4 Legally Binding

The act strictly under the legal regulator showed on the regulation which Offshore Petroleum and Greenhouse Gas Storage (Safety) Regulations 2009. Select Legislative Instrument 2009 No. 382 as amended made under the Offshore Petroleum and Greenhouse Gas Storage Act 2006.

In addition, the relationship with other regulations made under the Act mentioned in 1.9 on the regulation;

> *The requirements of these Regulations are in addition to the requirements imposed on a person by any other regulations made under the Act.*

5.7.5 Relation to Risk Acceptance Criteria

The use of ALARP framework has been used in the regulation, specifically divided into two areas where unacceptable/intolerable region and broadly acceptable region. The regulation mentioned;

> *Risk is most commonly represented on an inverted triangle as increasing from a 'broadly acceptable' risk region, through a 'tolerable' region only if shown to be ALARP, to an 'intolerable' region, in which the risk cannot be justified on any grounds. Such diagrams also typically introduce numerical thresholds between the risk bands, often in terms of the Individual Risk Per Annum (IRPA) of a fatality. Operators may find it helpful to think of risk in terms of the inverted ALARP risk triangle; however it is important to be aware that the overall provisions the operator has to make through the safety case need to consider hazards and risks in all regions of the triangle.*

5.7.6 To what extent does ALARP mean to use cost-benefit analysis?

The fundamental approaches that need to consider regarding ALARP demonstration have been used for reducing risk. The operator can consider the approach to reduce risk to a level that is ALARP. In order to implement that approach, cost-benefit is one of them; in relation to the cost-benefit analysis, the regulation mentioned that;

> *Cost benefit analysis [CBA] – the numerical assessment of the costs of implementing a design change or modification and the likely reduction in*

fatalities that this would be expected to achieve. The quality of the modelling and the data will affect the robustness of the numerical estimate and the uncertainties in it must always be borne in mind when using the estimate in risk management decisions. In making this assessment there is a need to set criteria on the value of a life or implied cost of averting a statistical fatality (ICAF). In reality of course there is no simple cut-off and a whole range of factors, including uncertainty need to be taken into account in the decision-making process.

5.8 ALARP principle in Singapore

5.8.1 Ministry of Manpower

The Ministry of Manpower is a ministry of the Government of Singapore that is responsible for the formulation and implementation of labor policies related to the workforce in Singapore. The Ministry was known as the Ministry of Labor until 1998 (MOM Singapore, 2021).

5.8.2 The Term

In Singapore, the regulation gives a clear term where ALARP (As Low As Reasonably Practicable) applied. The regulation has a subject with ALARP Demonstration Guidelines as a title. One of the statements of ALARP in safety case - purpose and key concept number 2 below;

The regime requires MHIs to demonstrate to regulators how risks from Safety Critical Events (SCEs) are being reduced to As Low As Reasonably Practicable (ALARP) and thereby ensuring safe operations in a sustainable manner.

In addition, ALARP principle stated on the control measures as below;

2.2. The MHD policy is that taking all necessary control measures (i.e. all "reasonably practicable" control measures) equate to reducing risks to ALARP.

5.8.3 The Scope

From ALARP demonstration guidelines, it can be seen that the scope of regulation can be read in conjunction with the requirements in the safety case assessment guide; in the safety case assessment guide listed the scope of assessment as follows; a). Descriptive aspects b). MAPP (Major Accident Prevention Policy) and SHMS (Safety & Health Management System), c). Predictive aspects d). Technical aspects e). Emergency response f). Assessment of ALARP.

5.8.4 Legally Binding

It can be obtained from the regulation where the acknowledgment of guide was jointly developed by the Safety Case Workgroup (SCWG) comprising representatives from the Major Hazards Department (MHD) and industry members of the Singapore Chemical Industry Council (SCIC). As well as all stakeholders in the MHI industry for feedback and support. MHIs should determine the level of information to support a given demonstration or requirement in the WSH (MHI) Regulations.

The role of SCWG is to support the enhancement of the process safety regulatory framework in Singapore by developing implementation proposals for Safety Case Regime, which coordinate with SCIC for the QRA (Quantitative Risk Assessment) workgroup to ensure revised QRA guidelines are fit for adoption into the safety case regime (WSH, 2016).

5.8.5 Relation to Risk Acceptance Criteria

When we look into the regulation, the single scenario target is one approach to achieve the goal. The goal of this scenario is the approach for evaluating whether the risk is reduced to the ALARP. As the regulation stated below;

> *3.3 Under the Safety Case regime, MHIs are required to perform ALARP demonstration for SCEs. By establishing a single scenario risk target, MHIs will be able to evaluate the risk of each SCE and determine, through the implementation of adequate and robust barriers, whether the risk is reduced to ALARP.*

SCEs stands for Safety Critical Events. Further, in order to establish the guideline, the Individual risk and/or societal risk approach has been used, referred to;

3.2 Most jurisdictions around the world, including Singapore, adopt the individual risk and/or societal risk approach for land use planning purposes. These approaches typically require the conduct of a Quantitative Risk Assessment (QRA), which presents risks in a cumulative manner.

Based on Aven (2015), Individual risks are assessed as the likelihood of death for a person or critical group of personnel who are most vulnerable to a certain activity due to their location, habits, or time period—Averaged over a homogeneous group of people, the annual frequency of an accident with one or more fatalities (typically a year). Meanwhile, according to Häring (2015), the risk that a group (e.g., the population of a country, workers in a company, etc.) is exposed to which is defined as societal risk or collective risk. For a company, for instance, demonstrating that the collective risk of the workers and those in the surrounding area is low enough.

To achieve a single scenario risk target, it is important to understand the scenario of approaches, as the regulation suggested in part 3.5 below;

3.5 The threshold for risk deemed "Unacceptable" and "Tolerable if ALARP" differs for new and existing facilities. The orange shaded region is deemed as "Unacceptable" for new facilities, and as "Tolerable if ALARP" for existing facilities. The target is also replicated in a tabular form, for new and for existing facilities.

It is important to know the level of risk to determine or make decisions about the safest work methods with the lowest possible time and cost. The discussion about the single scenario risk target and tabular form will be discussed more in chapter 6.

5.8.6 To what extent does ALARP mean to use cost-benefit analysis?

Disclosed from the regulation that to provide evidence that the risks are reduced to a level that is ALARP, it is a fundamental requirement to show the clear link between the MAH (Major Accident Hazard) identification and risk assessments and the measures taken to make the risks ALARP in part number 324, a specifically cost-benefit analysis approach considered as below;

c) Cost benefit analysis (CBA) – the numerical assessment of the costs of implementing a design change or modification and the likely reduction in risk that this would be expected to achieve. CBA may be used in cases where it is *difficult to determine whether the cost is justified after completing risk assessments of sufficient rigour. The UK HSE website provides an in-depth explanation on the uses and limitations of using CBA for ALARP decision making. MHIs (Major Hazard Installations) using CBA shall ensure that all data and assumptions are justified in the safety case.*

6 Discussion

Based on observations and findings made in the previous section, there are several findings with respect to the discussion, and following the review will be explained in this chapter as follow:

1. Regulatory Scope
2. What do they mean by ALARP?
3. Relation to Risk Acceptance Criteria
4. To what extent does ALARP mean to use cost-benefit analysis?
5. How the ALARP should be verified?
6. Minor Limitation

Each of them will be discussed in the following sections.

6.1 Regulatory Scope

Firstly, in Norway, regulatory responsibility for safety, emergency preparedness, and the work environment in the petroleum industry activities in Norway, both onshore and offshore, is carried out by PSA (Petroleum Safety Authority). The scope of regulations, is divided into three subjects, namely applicable to the petroleum activities at onshore facilities, other activities at onshore facilities, and apply to offshore petroleum activities. They are determining the scope of the regulation to help the decision-making for protection and prevention approach in accordance with the job desk of each work area. Unfortunately, the regulation is not stated the specific regulation for the Svalbard area; in other words, those regulations did not apply for Svalbard, whereas they are under Norway's governance. Legal binding is important for the regulation, written regulatory rules made by the competent authority, in this case, PSA Norway. The regulations are made based on the Act; hence before carrying out exploration, production, transportation, and utilization activities, the operator can understand and follow respectable law. The Act becomes a strong and official role of the government or related authorities.

Secondly, in the United Kingdom, the encouragement, regulation, and enforcement of workplace health, safety, welfare, and for occupational risk research under HSE (Health and Safety Executive) UK responsibility. The Health and Safety Executive (HSE) is the

UK's national regulator for workplace health and safety. In the United Kingdom, the scope of the ALARP principle generally applied to offshore installations or related operations, such as supply vessels, diving activities from a diving support vessel, loading vessels, heavy lift vessels, and service vessels. Facilities for operation processes must be adequately constructed to perform safely while adhering to technical guidelines. Regarding the legally binding, the use of regulation applied for all offshore employers especially for OSCR (The Offshore Installations (Safety Case) Regulations), can be seen in the regulation for OSCR 1992 required a safety case to include a demonstration that major hazard risks are ALARP. The law requires stronger standards than the ALARP standard.

Thirdly, in Denmark, the regulation was established under The Danish Work Environment Authority (Offshore olie-og gasaktiviteter Arbejdstilsynet). This regulator sets the overall framework for the Danish Working Environment Authority's activities. The scope regulation has been applied for both onshore and offshore. And also, special offshore conditions between technical aspects and related to mobile installation, international conditions are also taken into account. The use of the ALARA principle to ensure that the operator/company follows the rules or regulations set by the authority hence the possibility of risk or accident occurring can be minimized. Based upon legally binding in the regulation, the ALARP principle under offshore safety legislation. The company can do activities in offshore oil and gas operations based on consideration from authorized acknowledge under the Danish Subsoil Act. One thing that interested, a special case in Denmark, where the regulator granted special rights or, in other words, sole concessions to A. P. Møller-Mærsk A/S and Mærsk Olie og Gas A/S as the first step in the development of the oil and gas industry there.

Fourthly, in Australia, the independent expert regulator for offshore petroleum facilities and operations in Commonwealth seas in terms of health and safety, environmental management, and structural and well integrity is under The National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). There are two subjects as mentioned in the regulation regarding the scope of work. In Australia, generally related to the facilities and offshore activities such as laying petroleum pipelines, including any manufacturing of such pipes, or doing maintenance on an existing pipe, vessels used to supply facilities or transit to or from facilities.

Fifthly, in Singapore, the internal guide is used by the Major Hazards Department (MHD) for the assessment of safety cases submitted by MHIs (Major Hazard Installations). The Major Hazards Department (MHD) is a joint-government department led by MOM (Ministry of Manpower). Regulation responsible for the formulation and implementation of labor policies related to labor in Singapore by MOM. The scope of the guideline covered into several aspects, such as the first, descriptive aspect, in general focus on facilities/process section. Second, Major Accident Prevention Policy and Safety & Health Management System both focus on the protection of people and the vicinity in relation to the installation and a commitment to provide and maintain a management system that addresses the issues. Third, Predictive aspects shall contain plans, maps, or diagrams with descriptions that clearly set out detailed information about the installations with potential for major accidents. Four, Technical aspects focus on Process Safety, Mechanical engineering, Electrical, control and instrumentation, and Human factors. Five, Emergency response, the safety case shall show basic information, for instance, a description of such equipment and systems and how these equipment or systems affect how a major accident is mitigated. Six, Assessment of ALARP, the safety case shall pull together the information from the risk assessment, for instance, shows that risk assessment has been used in an appropriate way as part of the process to reduce risks on the installation to ALARP.

Each country has different guidelines and details in its laws or regulations; Norway has regulations for operators/companies but does not provide specific values regarding requirements such as numbers because operators/companies are expected to provide their own safety measurement but still follow the regulations in the country. Under the Petroleum Safety Authority of Norway. Meanwhile, in the UK, regulations are given to operators/companies with significant guidance. Denmark uses regulations/standards for safety guidance based on the United Kingdom. Australia and Singapore also have significant laws and regulations for operators/companies working in their territories.

6.2 What do they mean by ALARP?

Firstly, in Norway, when reducing risk, the operator/company needs to use technical solutions for operational and organizational activities with the best results but provided the costs are grossly disproportionate to the benefit gained as we know from the concept of ALARP according to Abrahamsen (2015) the regulation implicit the concept of

ALARP even though not explicitly call the concept with a term of ALARP/ALARA/SFARP. We also use NORSOK as another reference in order to support the findings in the regulation. NORSOK is a standard developed by the petroleum industry in Norway to ensure adequate safety, cost-effectiveness and etc.; for the development of petroleum industry operations, the NORSOK standard is also used as a reference by regulatory authorities (Standard, 2021).

Secondly, in the United Kingdom, the term ALARP has been used in the regulation; United Kingdom established ALARP even before the term ALAP (As Low As Practicable) arise (Ale, 2015). It can be said that the United Kingdom is the pioneer of the ALARP principle. Many papers or journals use the HSE United Kingdom as a reference. Common law in England leads to consideration of what is reasonable effort to avoid causing damage to a certain level of risk when the damage cannot be completely excluded. These considerations lead to the definition of ALARA or ALARP in English especially.

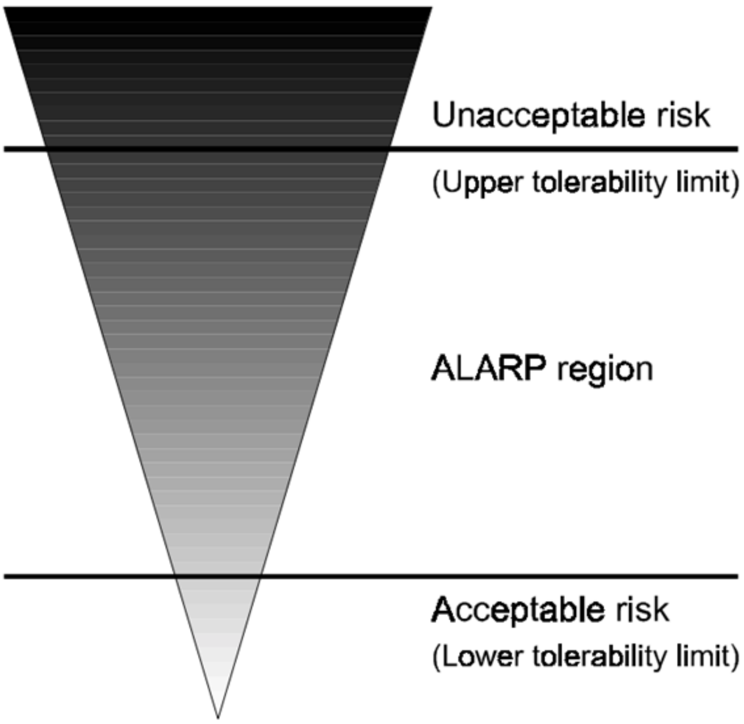
Thirdly, in Denmark, unlike regulations in other countries, in Denmark, the use of the word ALARP (As Low As Reasonably Practicable) can be equated with the word ALARA (As Low As Reasonably Achievable), or other words as synonyms. Both terms the ALARA and ALARP, have been used for the regulation.

In Australia, the term ALARP is explicitly used in the regulation; other words such as ALARA either SFARP are not pointed out in the regulation. Offshore petroleum activities cannot be started by law until NOPSEMA has reviewed and approved detailed risk management plans that document and demonstrate how the company/operator will manage health safety and the environment with the ALARP principle.

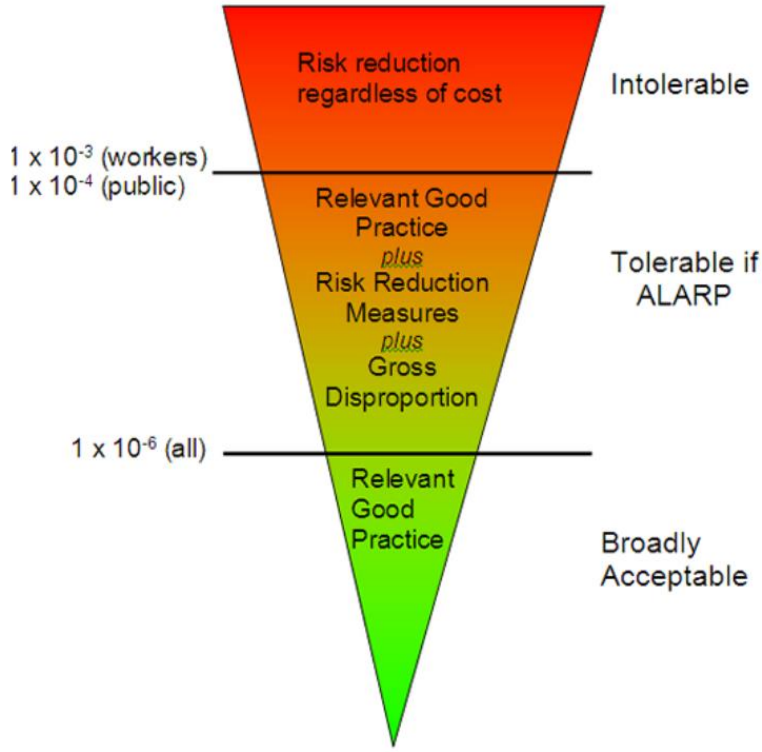
In general, the term ALARP is widely used in various countries; ALARP is becoming a more familiar word, especially in the safety sector of the oil and gas industry. If the term ALARP is not explicitly stated in each country's regulations, the phrase "as low as reasonably practicable" or "grossly disproportionate to the benefit obtained/gained" can represent the term ALARP.

6.3 Relation to Risk Acceptance Criteria

In Norway, basically, there are two regions between unacceptable risk and acceptable risk. The regulation implied that in the range between acceptable and unacceptable risk, the risk level should be reduced as much as possible. The most common way to determine what is possible is to use cost-benefit analyses to decide whether or not to implement certain risk-reduction measures. However, uncertainty is often not considered in the cost-benefit analysis. The upper tolerability limit is usually defined, while the lower tolerability limit is usually undefined. But the use of an effective approach will not prevent it; it is implied ALARP evaluations of risk-reducing measures will always be required. The risk acceptance criteria are relevant for personnel, environment, and assets in relation to the ALARP principle. The petroleum regulation in Norway also says anything below the risk acceptance criteria that is where the ALARP principle applied. If it is above the risk acceptance criteria, then the solution is not acceptable; if it is below may still not be accepted until the risk has been reduced to "as low as reasonably practicable".

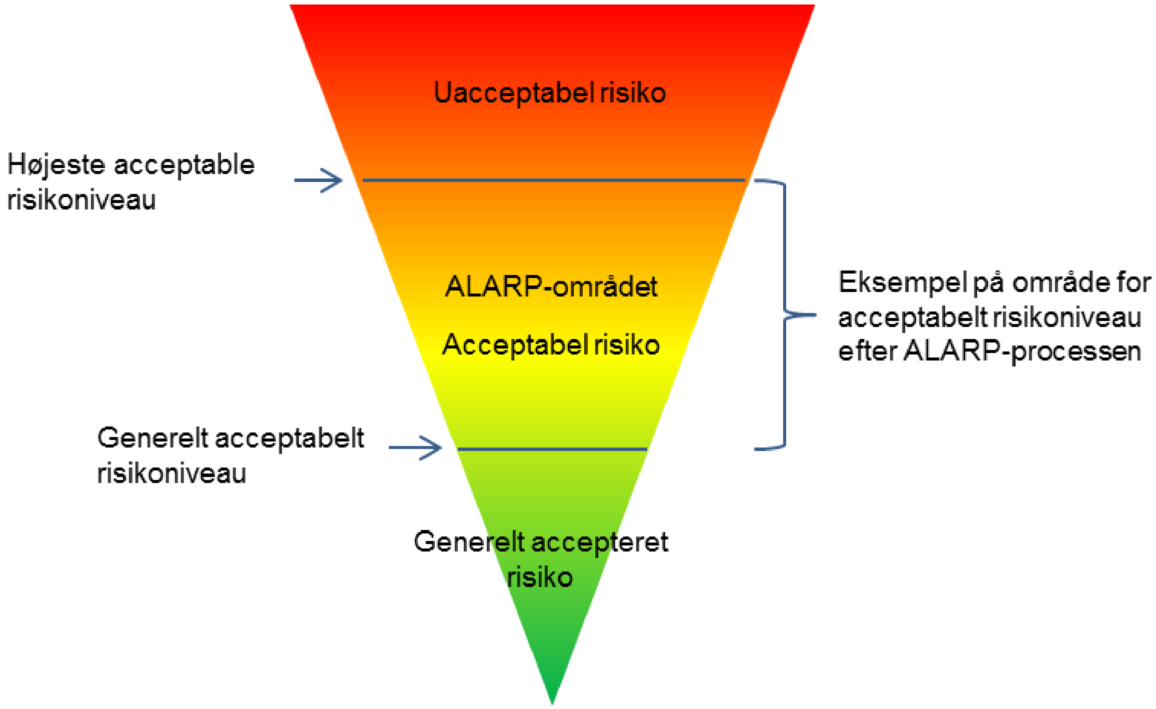


Risk acceptance criteria in the United Kingdom divided into three areas based on the dark zone at the top represents an intolerable region, lighter dark color in the middle described as the tolerable region, and at the bottom with bright color as a broadly acceptable region, retrieved from Control of Major Accident Hazards (COMAH) guidance in HSE UK below the figure types of ALARP demonstration presented;



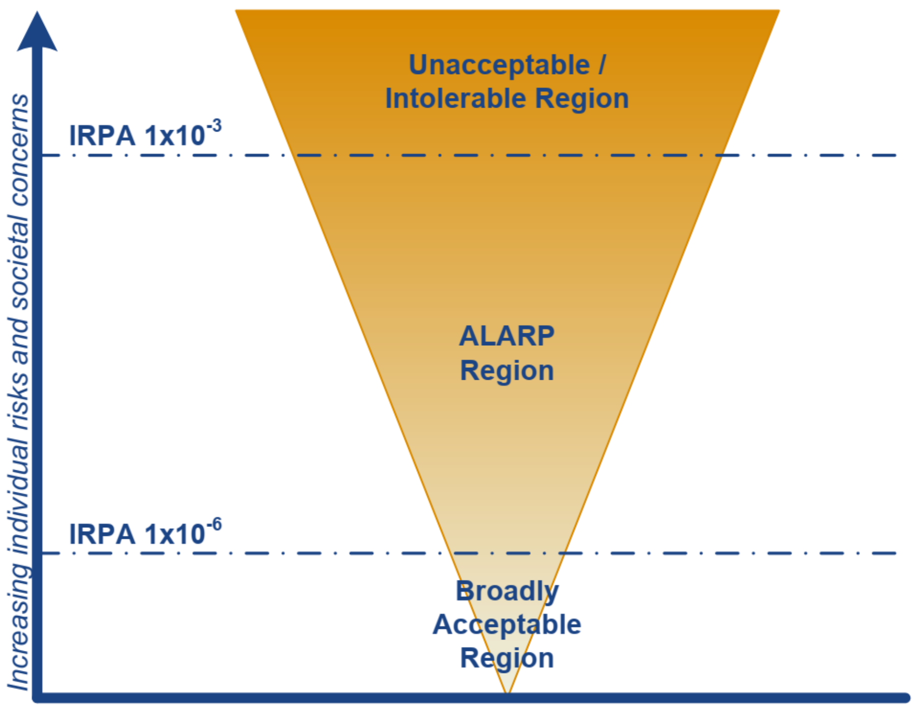
As we can see on the intolerable area, the frequency upper limits for workers at 1 x 10-3 and the public at 1 x 10-4. These numbers will be used as the parameter if the risk in this zone, then the ALARP principle cannot be demonstrated; action must be performed to lower the risk nearly regardless of the cost. Next is the tolerable area; a case-specific ALARP demonstration is necessary if the hazards are in this region. The demonstration's scope should be proportional to the level of risk, the level of frequency more or less between 10 x 10-3 or 10 x 10-4 to 1 x 10-6. Then into the broadly acceptable area, the frequency number is 10 x 10-6 that applies to all. If the risk is in this area, the ALARP demonstration might be based on adherence to codes, standards, and established good practice. These must be shown to be up-to-date and relevant to the operations in question. If the identified measure is based on engineering considerations, and it cannot be shown that the cost of the measure is grossly disproportionate to the benefit gained, the operator should look systematically at the risks from the operation, in a proportionate way, a list of measures that could be implemented to reduce those risks, and then if the identified measure is based on engineering considerations, and it cannot be shown that the cost of the measure is grossly disproportionate to the benefit gained, then the operator is obligated to put such measure in practice. Inspectors will require guidance on determining if the operator's argument of gross disproportion is valid. Basically, in the United Kingdom, the lower limit where it is considered as a safe zone, you do not need to do any kind of circumstances.

In Denmark, in relation to risk acceptance criteria, the ALARP triangle presented as below;



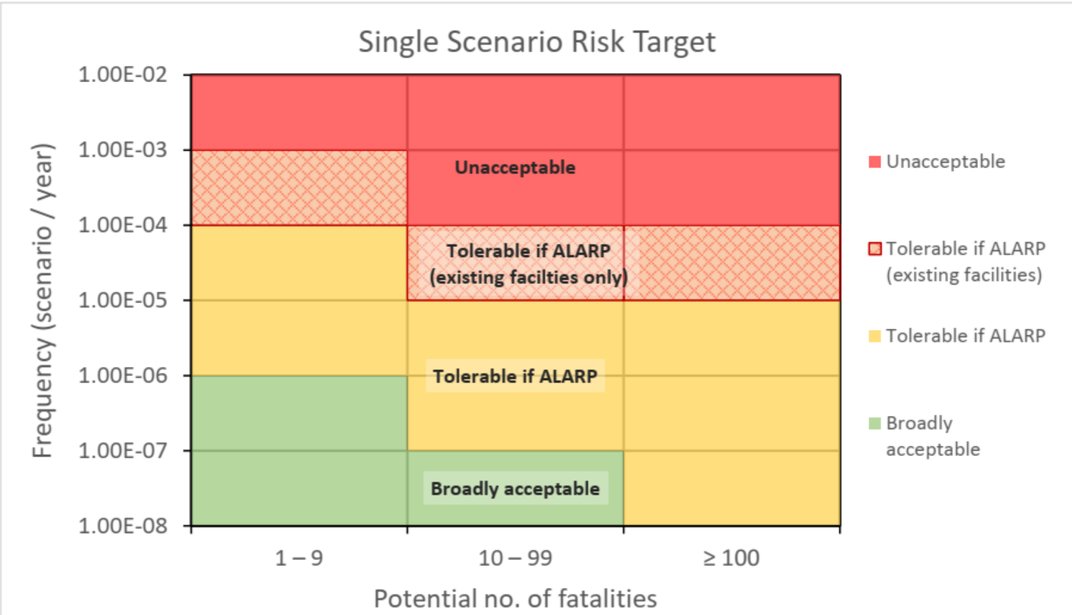
Regarding the figure above, we can see that the area is divided into three aspects in Danish, where Uacceptable risiko (Unacceptable risk), Acceptabel risiko (Acceptable risk), Generelt accepteret risiko (Generally accepted risk). Højeste acceptable risikoniveau (Highest acceptable level of risk) which is in area Unacceptable risk has to be considered, a particular risk must be kept below the limitations defined as the highest acceptable level of risk, for example, limit values and the enterprise's own acceptance criteria in all circumstances. However, this is not enough to qualify a risk as having been lowered in line with the ALARP principle. ALARP-område (ALARP area) is connected with Acceptable risk; the risk level between the highest acceptable level of risk and the usually acceptable level of risk is known as the ALARP region. In this region, risk reduction must be undertaken in line with the ALARP principle. This area also considered as Eksempel på område for acceptabelt risikoniveau efter ALARP-processen (Example of area for acceptable risk level after the ALARP process). Then, Generelt accepteret risiko (Generally accepted risk) when risks are at or below the generally accepted threshold of risk, they are deemed bearable, and no further precautions are usually required. The measures can be implemented unless it can be demonstrated that this is not reasonably practicable. Retrieved from Concepts related to offshore oil and gas operations (DWEA) maximum tolerable risk (fatalities per year) for workers 10-3 and the public 10-4, meanwhile broadly acceptable risk (fatalities per year) for workers 10-6 and the public 10-6. The use of risk acceptance criteria in Denmark uses a lot of references to regulations from the United Kingdom; it might be better if Denmark uses regulations made with its own standards because the working area and area of oil and gas operations are different for operators/companies.

In Australia, in relation to risk acceptance criteria, the regulation is shown ALARP triangle as presented below;



There are three regions in this ALARP triangle, Firstly the Unacceptable/Intolerable region, where the risk cannot be justified for any reason. The number of individual risks per annum represents as 1 x 10-3. This region can be considered as "Untreated Risk". Regardless of the circumstances, therefore, it must be reduced. Then ALARP region can be considered as a 'tolerable' region as long as the As Low As Reasonably Practicable principle applies. To keep risk at the ALARP level requires ongoing action to ensure control measures are maintained. For example, a cost-effectiveness control measure was proposed in order to reduce risk. The risk should be reduced to a level that is ALARP. Next, a broadly acceptable region, in this region can consider reducing the risk further, but in the future, perhaps the costs for risk treatment are grossly disproportionate to the risk reduction. The use of Australian risk framework figures for the upper (10-3) and lower limits (10-6) for individual risk per year is the same as the use of risk framework figures in the United Kingdom.

In Singapore, in relation to risk acceptance criteria, establishing a single scenario risk target to demonstrate the risks of the identified scenarios are reduced to ALARP. This approach has the purpose of managing risks arising from major accident hazards. Below the single scenario risk presented;



From the figure above, a single scenario risk target is divided into four areas. The unacceptable area represents a red color, where unless risk reduction steps are performed to decrease the risk level to ALARP further, the risk is deemed unacceptable. MHIs would need to create action plans and put risk-reduction measures in place as soon as possible. Responsibilities, accountability, and a timeline for implementation should all be included in the action plans. If ALARP is tolerable, where risk is considered tolerable if it can be proved in a systematic and logical manner, based on sound engineering principles, each incremental sacrifice made to deploy more risk reduction methods provides no meaningful additional benefit. On the basis of existing technical capabilities, the assessor should also assess whether a control measure can be implemented. Broadly Acceptable, If good practices and sound engineering principles applicable to these single scenarios have been followed, and current precautions are effective and properly managed, the risk is deemed to be broadly acceptable. Below frequency for each risk level presented;

Consequence (no. of fatalities[3])	Frequency range for each risk level (scenario / year)		
	Unacceptable	Tolerable if ALARP	Broadly Acceptable
1 – 9	> 1E-04	> 1E-06 – 1E-04	⩽ 1E-06
10 – 99	> 1E-05	> 1E-07 – 1E-05	⩽ 1E-07
⩾ 100	> 1E-05	⩽ 1E-05	-

From all the regulations it is interesting to point out the difference and similarity from each country. Firstly, the difference to those regulations, as we can see the risk acceptance criteria in Norway, the company or operator should set their own criteria, the authority which Petroleum Safety Authority, only set the acceptance criteria where in Norway is 10-4 for frequency of main safety function. While another country, such as the United Kingdom, sets the risk acceptance criteria with two specifics where for the public is 1 x 10-4 and workers is 1 x 10-3, then Australia with 1 x 10-3 as their Intolerable region for risk acceptance criteria subject. In line with Singapore, the risk acceptance criteria shown the number of the unacceptable region with 1.00E-03. Meanwhile, in Denmark, the specific number for the risk acceptance criteria is not explicitly shown, but the figure quite similar, which is carrot diagram shape. Therefore, only in Norway the specific number for a set of risk acceptance criteria a bit different, which 10-4; it might be similar to the UK with the public subject, but we mainly focus on the worker's area. The similarity, in Australia, the risk framework is similar to the United Kingdom in the guidelines on how to assess ALARP are provided, along with examples of upper and lower risk limits (10-3 and 10-6, respectively, as in the United Kingdom). Also, in Denmark, the set of risk acceptance criteria is the same, but they use matrix shapes for the divided areas.

6.4 To what extent does ALARP mean to use cost-benefit analysis?

In Norway, in relation to the cost-benefit analysis, as mentioned above, there are at least three purposes of the use cost-benefit analysis: 1). Type I is considered as the use of CBA in an ALARP evaluation for risk to assets 2). Type II is considered as the use of CBA in an ALARP evaluation for personnel 3). Type III is considered as the use of CBA in the ALARP consideration for Emergency Preparedness. We conclude from Abrahamsen

(2007) that cost-benefit analyses ignore uncertainty to a large extent, and this practice has been questioned. The cost-benefit analyses do not give sufficient weight to uncertainties since they are based on a risk-neutral attitude to risks and uncertainties, which is inconsistent with the usage of the cautionary principle and ALARP. Values for cost-benefit analysis are used to assess the ALARP principle.

In the UK, cost-benefit analysis is one approach to assist the decision-making process. For decisions on the ALARP principle, the argument from the cost-benefit analysis is not the only one that is used for good practice. It is also stated in the regulation that cost-benefit analysis is often a useful tool for judging the balance between the benefits of each option and the costs incurred in implementing it.

The cost-benefit analysis aspect in Denmark can be obtained from the regulation where if the costs are grossly disproportionate to the additional risk reduction achieved through risk reduction measures, the risk reduction measures can be eliminated, provided good practice is followed and appropriately documented. British Health and Safety Executive’s website use as one of the references for regulation in Denmark. In line with the statement above, where the United Kingdom is a reliable source as a reference for the regulation is valid.

In Australia, the cost-benefit analysis in the regulation uses a numerical estimate of the expenses of implementing a design change or modification, as well as the potential decrease in fatalities that would follow. The robustness of the numerical estimate is influenced by the quality of the modeling and data, and the uncertainties in it must always be considered when using the estimate in risk management decisions. In order to make this judgment, standards for the worth of a life or the implied cost of avoiding a statistical fatality must be established (ICAF).

In Singapore, regarding cost-benefit analysis, the regulation quite similar to Australia regulation, the numerical assessment used for the cost of implementing a design change or modification, as well as the potential decrease in risk that this would result in. CBA may be utilized in situations where it is difficult to identify if a cost is justified after doing thorough risk assessments.

The cost-benefit analysis also has the difference and similarity in a way. The difference obviously between Norway, United Kingdom, and Denmark, those countries basically used the same principle, which is the ALARP principle, but the interpretation is quite different. For instance, in Norway, to determine what is an acceptable risk level without prior satisfaction of risk acceptance criteria, which all are evaluated within an As Low As Reasonably Practicable context. While in Denmark, the justification must include information about the costs associated with establishing risk reduction measures and an assessment of whether these costs are grossly disproportionate to the benefits gained by the risk reduction. On the other hand, the similarity found in Australia and Singapore, where both countries use the numerical assessment of the costs of implementing a design change or modification for a reduction in risk.

6.5 How the ALARP should be verified?

In Norway, a cost-benefit analysis is recommended as part of the ALARP assessment. However, the cost-benefit is one way to verify ALARP but not the main one. For a demonstration of the ALARP, several steps are recommended by the NORSOK standard, such as; (1) Determine what activities may be taken to reduce risk. (2) Measures to reduce risk are evaluated (3) Decision-making (4) Accepted and rejected risk reduction activities are documented.

In the UK, to verify ALARP in decision-making, cost-benefit analysis helps by providing a monetary value for costs and benefits. However, cost-benefit analysis is not the only argument used to make ALARP decisions; HSE does not expect task holders to conduct a detailed cost-benefit analysis for many ALARP decisions. A tighter cost-benefit may be more beneficial; task holders may face some uncertainties such as the frequency of occurrence and the number of potential deaths involved. Sensitivity analysis can be used to address these uncertainties by highlighting appropriate plausible assumptions and to assess the robustness of the cost-benefit analysis by the task-holder in line with the assessing HSE. The stronger the results of the cost-benefit analysis, the more suitable it is for the ALARP decision-making tool.

Meanwhile, to verify ALARP is not explained or there is no information on formal regulations in Denmark. However, under the Danish Offshore Safety Act where the operator and the owner, respectively, are responsible for ensuring that contractors working for them get the essential health and safety instructions, as well as for instructions critical to the avoidance of serious environmental accidents. As well as the hazards of significant environmental incidents have been discovered, assessed, and reduced to a level as low as reasonably practicable.

In Australia, according to the NOPSEMA guidance notes, there is no one correct way to ‘’show’’ ALARP. For each major accident event for the facility, a demonstration will contain these; (1) Identify and think about prospective risk-reduction strategies (both accepted and rejected); (2) Analysis of each of the identified actions and establishment of views on the safety advantages of each of these acts; (3) Assessment of the identified measures' reasonable practicability, as well as their adoption or implementation. (3) Process and outcome documentation, which will be summarized in safety cases. The ALARP will be achieved and justified by finding a balance between benefits in terms of risk reduction and controls. For instance, if the advantages of a control measure significantly exceed the cost, it is nearly always implemented unless there is a compelling reason not to. But, on the other hand, the costs considerably exceed the benefits; it is simple to show that control methods are ineffective because other choices will almost surely reduce the same risk at a lower cost. If the benefits and costs are equal, more consideration may be required before adopting or rejecting a control approach.

In Singapore, based on safety case technical guidelines, there is no established approach to show that the essential control measures have been found and will continue to be established in order to decrease ALARP risks. There are, nevertheless, some fundamental principles that may be utilized to assist the production of evidence and justification for a Major Hazard Installation in a safety case. Depending on the installation, Major Hazard Installations may use one or more of these techniques. If good practice and engineering principles are used as the sole justification for an ALARP, the Main Hazard Installation must demonstrate that: (1) good practice and engineering principles are applicable to the Main Hazard Installation situation; (2) Each accepted standard must be current and relevant (especially for new projects and modifications, according to the most recent at the time of implementation); (3) When a standard provides for more than one conformance option, the selected alternative makes the risks as low as reasonably practicable (4) Good engineering practice and principles keep risk to a minimum. Unless, for instance, the risk is well recognized and the uncertainty is small, it is not enough to presume that using current good practice and engineering standards will ensure that the risk is ALARP.

As discussed above, the use of cost-benefit analysis is used for ALARP assessment but is not a benchmark because, basically, the cost-benefit analysis does not provide an element of uncertainty. In line with the United Kingdom, the use of cost-benefit analysis is not the only argument used to make ALARP decisions; other approaches such as sensitivity analysis are carried out to ensure decisions for the ALARP principle with stronger cost-benefit analysis results. While in Denmark, it is not explained about the verification or justification of the ALARP principle, but the respective operator/company is responsible for ensuring that the safety of workers and the work environment must be in safety to avoid serious accidents under the statutory regulations. Whereas in Australia, there is no one correct way to "show" ALARP. However, for every risk, as much as possible, control measures are carried out with a prospective risk reduction strategy as for low as reasonably practicable. Furthermore, in Singapore, engineering principles are used as the sole justification for ALARP; when the standard provides more than one conformance option, the chosen alternative keeps the risk as low as possible as well as practices in line with good engineering principles keeping risk to a minimum.

6.6 Minor Limitations

We also found out the minor limitation or minus point in the regulation, which presented in the table below:

	Norway	United Kingdom	Denmark	Australia	Singapore
Limitation	§ 2 Scope of application These regulations do not apply to Svalbard. § 6 Definitions a) The responsible party: The operator and others participating in activities covered by these regulations, without being a licensee or owner of an onshore facility.	51 The 1992 OSCR required a safety case to include a demonstration that major hazard risks are ALARP. 9). In practice the ALARP standard remains for acceptance except where the law requires a stronger standard	"Generally acceptable level of risk" means: "The level of risk at which additional use of the ALARP principle is unnecessary." (Executive Order no. 1198, section 2(1), no. 5).	(2) An object of these Regulations is to ensure that safety cases for facilities make provision for the following matters in relation to the health and safety of persons at or near the facilities: (d) monitoring, audit, review and continuous improvement	There is no specific requirement for MHIs to include copies of operating procedures and/or associated documentation in their safety case

In Norway regulation, there is no specific regulation in the Svalbard area regarding safety measurement even though under Norway territory. Also, the responsible party stated that for the operator without being a licensee or owner of an onshore facility. This could lead to an unsafe working situation because the licensee is important in order to understand the scope of work. In the United Kingdom, it can be seen that there is any inconsistency between the ALARP principle of regulation and the law that requires stronger standards; ALARP should have been in a strong and clear law. In Denmark, probably the principle of additional ALARP is not really urgent, but the integrity of supervision must still be carried out hence the level of risk remains in the As Low As Reasonably Practicable subject. In Australia, focus on continuous improvement, the detail of this subject is not really clear. Continuous improvement can increase the effectiveness of risk management work. Consistent improvement is a continuous cycle of improving the safety system for an organization. In Singapore, there should be a requirement regarding operating procedures in safety cases; every organization is required under regulator to have regulations and policies regarding the safety of workers.

7 Conclusion and Recommendation

After reviewing the regulations in each country, the main findings of this thesis are summarized, and recommendations are also given as follows:

7.1 Conclusion

The aim of this master thesis is to review the ALARP principle from a different country and trying to find the difference and similarities of the regulation. Regulations of some countries have their own advantages and disadvantages, but the point is that the risk must be reduced to a level that is as low as reasonably practicable. The use of ALARP from the five countries, namely Norway, the United Kingdom, Denmark, Australia, and Singapore, the format of using the ALARP principle has a different approach across these countries. Prior to carrying out activities, the operator/company submit a permit in the form of documentation to the authorities for approval, especially related to safety aspects for operations, designs, and assets. The interpretation of the use of the ALARP principle has obstacles to justify or verify it; it is necessary to have a clear concept or tool hence the ALARP principle can work optimally, such as justifiable cost, which the regulator must define how to implement. The most obvious difference is in Norway with other countries. Where Norway gives the operator/company to set the acceptance criteria. The values for cost-benefit analysis are used to assess the ALARP principle. There are pros and cons in the application of risk acceptance criteria carried out by operators/companies; the authority only provides an upper limit value hence the implementation of the approach can be different. While the pro thing is that the operator/company better understands in regard to face risk and be adaptable to what approach can be taken by the management. In other countries, the use of risk acceptance criteria uses an upper limit with a value of 1 x 10-3, such as the United Kingdom, Australia, and Singapore; in Denmark, the use of this value is not attached, but the references used are from the UK, from the use of the risk acceptance criteria, each country has advantages in terms of approaches that have been taken or experienced therefore the benchmarks of regulation become clear. However, the disadvantage is where the authorities have different work areas and zones. Therefore adaptations need to be made to use these criteria. The risk assessment will involve that each practical hazard, the risks associated with them, supervisory personnel, and control measures are properly determined to a tolerable level.

In this conclusion, the United Kingdom, which in my opinion, is more comprehensive in implementing the ALARP regulations because all are under the supervision of the authorities, and many other countries use the UK as a reference for risk acceptance criteria.

7.2 Recommendation

Based on the result, there are several points that can be improved from the ALARP regulation. Suggestions for further studies are;

1. The use of risk acceptance criteria in Norway may need to be evaluated because the authority gives the operator/company set the risk acceptance criteria. It would be coherent if the authorities set the criteria.
2. The use of cost-benefit analysis is not the only tool for ALARP verification. Therefore, a more comprehensive verification tool is needed to support decision-makers based on the ALARP principle.
3. The authority may need to create a special team to oversee the implementation of the principle of using ALARP in each sector, hence ensuring the risk acceptance criteria are within safe limits/tolerable area.

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Appendix A ALARP Regulation from Each Country

A.1 ALARP principle in Norway

§ 11 Risk reduction principles

Harm or danger of harm to people, the environment or material assets shall be prevented or limited in accordance with the health, safety and environment legislation, including internal requirements and acceptance criteria that are of significance for complying with requirements in this legislation. In addition, the risk shall be further reduced to the extent possible.

In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved.

If there is insufficient knowledge concerning the effects that the use of technical, operational or organisational solutions can have on health, safety or the environment, solutions that will reduce this uncertainty, shall be chosen.

Factors that could cause harm or disadvantage to people, the environment or material assets in the petroleum activities, shall be replaced by factors that, in an overall assessment, have less potential for harm or disadvantage.

Assessments as mentioned in this section, shall be carried out during all phases of the petroleum activities.

This provision does not apply to the onshore facilities' management of the external environment.

A.2 ALARP principle in the United Kingdom

Schedules and guidance

247 For each type of safety case or notification required by regulations 6-11 and 17, a corresponding Schedule lists specific matters to be included. Each Schedule should be considered with regulation 12 (for safety cases) and the supporting guidance. The remaining Schedules deal with the content of verification schemes, arrangements for appeals under regulation 24 and miscellaneous amendments.

Schedule 1 Particulars to be included in a design notification or a relocation notification

248 Duty holders should send the notification with the level of detail that it is reasonable for them to know at the time of submission. They should not delay the notification to include detailed design information.

1 The name and address of the operator of the installation.

2 A description of the design process from an initial concept to the submitted design and the design philosophy used to guide the process.

3 A description of –

(a) the chosen design concept, including suitable diagrams, and a summary of the other design options, which were considered;

(b) how the chosen design concept is intended to ensure –

(i) compliance with the requirements set out in regulations 5 and 10 of the Offshore Installations and Wells (Design and Construction, etc.) Regulations 1996(a); and

(ii) that risks with the potential to cause a major accident are reduced to the lowest level that is reasonably practicable; and

(c) the criteria used to select the chosen design concept and the process by which the selection was made.

4 A description of –

(a) the principal systems on the installation;

(b) the installation layout;

(c) the process technology to be used;

(d) the principal features of any pipeline;

(e) any petroleum-bearing reservoir intended to be exploited using the installation; and

(f) the basis of design for any wells to be connected to the installation.

249 The notification should describe the principal features of the design of structure and plant. It should also describe, by reference to safety margins incorporated in the design and to relevant criteria and codes of practice, how the preferred design option will reduce risks to as low as is reasonably practicable (ALARP). In this connection it will be appropriate to show how risk reduction will be achieved through the application of the concept of inherently safer design – see paragraphs 136-137. Account should also be taken of the requirements of DCR regulation 5 throughout the life cycle of the installation - see A guide

to the integrity workplace environment and miscellaneous aspects of the Offshore Installations and Wells (Design and Construction, etc) Regulations 1996. Suitable diagrams (to scale where necessary) with the description in the notification will enable readers to gain an overview of the installation, its plant, connected wells, pipeline connections etc.

A.3 ALARP principle in Denmark

1.6. ALARP demonstration

Demonstration that risks have been reduced in accordance with the ALARP principle, including that good practice has been used, when available; and including a description of cases in which risks have not been further reduced and the reason why there is a gross disproportion between costs and risk reduction.

3.2. Risk reduction

The fundamental principle in the offshore safety legislation is that operators as well as enterprises responsible for operations must reduce risks associated with their operations to a level which is as low as reasonably practicable (ALARP).

Risk is the combination (the product) of the likelihood and consequences; i.e. in order to reduce the risk, it is necessary to focus on reducing the likelihood that the hazardous events occur (prevention) and on reducing the consequences of events if such events do occur.

The following general hierarchy for risk reduction should be applied, see, for example, the DS/EN ISO 17776 standard:

1. Prevention (elimination or reduction of the likelihood that potentially hazardous events occur).
2. Detection (transmission of information to a control point).
3. Control (systems that control a hazard to minimise or remove consequences).
4. Mitigation (technical mitigation of consequences of hazardous events).
5. Emergency response (including fire equipment, life-saving appliances, etc.).

Where reasonably practicable, risk reduction must be built into the installation by taking the following preventive measures:

• reduction (reduce the magnitude or frequency of the hazard, or the duration of the exposure or the event arising from the hazard),

• substitution (replace hazardous activities, substances and materials with less hazardous ones),

• mitigation (e.g. sectioning of processing installations, ESD systems, conducting the process at lower temperatures or pressures), or

• simplification (simple design of installation, building and operations so as to reduce the need for processing equipment and control, and thereby reduce the risk of human errors).

See also the principles of prevention mentioned in Annex 1 to the DWEA guideline on risk management in connection with offshore oil and gas operations.

When the preventive measures have been assessed, measures must be taken to mitigate effects (consequences) of a potential hazardous event when such event has occurred. Such measures may include detection of gas or smoke, fire water mains and active and passive fire and explosion protection. Next, emergency response must be assessed. This may include manual fire fighting, temporary refuge, escape options and evacuation and life-saving systems, etc.

Choice of risk reduction measures will be influenced by

• technical feasibility,

• the impact of the measure,

• the costs and risks of implementing the measure, and

• the degree of uncertainty when assessing risks or the method to reduce the risks, including human factors.

A risk reduction measure must be implemented if it is “reasonably practicable”. What is “reasonably practicable” is not necessarily the same as fully “technically feasible”, which means that the operator must assess whether there is a gross disproportion between the effect of implementing the risk reduction measure and the associated costs (money, time, trouble). Assessing what is reasonably practicable typically involves a choice between several technical or operational solutions leading to different degrees of risk reduction.

When choosing a solution, the following conditions must be met as a minimum:

• Legislative requirements must be complied with, including limit values.

• Good practice in the area must be used.

As a general rule, recognised norms and standards in the area must be conformed to, but it must be assessed whether it is possible to reduce the risks further in accordance with the ALARP principle. For example, this may be relevant if the norms and standards applied are not up-to-date, or if good practice in the area would lead to a lower risk.

3.4. Reasonably practicable

When assessing what is reasonably practicable, it must be assessed whether there is a gross disproportion between the advantages in the form of preventing fatalities, personal injuries or occupational diseases that are achieved due to the risk reduction effort in the current situation, and the costs incurred when implementing the risk reduction measure (money, time and effort). The outcome of this assessment, and the resulting decision on whether further risk reduction should be implemented, depend on the specific situation.

In the event that the enterprise has a choice between a range of risk reduction measures, none of which demonstrates a gross disproportion between the risk reduction achieved and the associated costs, the DWEA will consider the risk reduction measure causing the lowest total risk of major accidents and the lowest risk to each of the other working environment factors as the measure reflecting ALARP and thus as the measure that should be implemented. Consequently, measures leading to less risk reduction than the measures above will not be considered as meeting the ALARP requirements of the Offshore Safety Act.

3.6. Assessment of risk reduction measures

The DWEA does not have an established practice for the size of disproportion operators should accept. This will be based on a specific assessment, including whether existing or new operations are involved; however, the greater the risk, the higher the costs to be accepted before the disproportion will be considered excessive.

The enterprise is responsible for justifying why risk reduction measures have not been implemented with reference to a disproportion that would not be acceptable under the circumstances. In this connection, the enterprise should investigate which disproportions have been accepted under similar circumstances elsewhere. In its assessment of the ALARP demonstration of the enterprise, the DWEA will take this into consideration.

If, after completing the notification procedure to the DWEA, a reasonably practicable means is identified that can further reduce risk for a new installation or a major conversion of an existing installation, the DWEA may require, following a specific assessment, that the risk reduction is implemented. This presupposes that the risk reduction measures should normally have been implemented as part of a good design according to the ALARP principle, but that they have not been implemented.

4. Demonstration that risks have been reduced to ALARP (ALARP demonstration)

The ALARP demonstration can be divided into:

• An ALARP demonstration for risks of major accidents, and

• An ALARP demonstration for other risks.

4.1.1. ALARP demonstration for risks of major accidents

The ALARP demonstration must provide evidence that all risks of major accidents have been reduced to a level that is ALARP.

The ALARP demonstration for risks of major accidents should include:

1. A list of persons involved in the ALARP process, including documentation that these persons are competent professionals who together possess the necessary qualifications to assess risk reduction measures in connection with the design and operations of the installation.
2. A description of risk reduction measures that have been assessed and implemented, including demonstration that all reasonably practicable measures have been identified.
3. A description of the risk reduction measures which have been assessed, but which have not been implemented, including satisfactory justification for not having implemented the risk reduction measures. The justification must include information about the costs associated with establishing risk reduction measures, and an assessment of whether these costs are grossly disproportionate to the benefits gained by the risk reduction. Where the costs are grossly disproportionate to the additional risk reduction achieved by means of the risk reduction measures, the risk reduction measures may be omitted, provided that good practice has been followed and appropriately documented.
4. Where good practice has been used as justification for not taking additional risk reduction measures, this must be appropriately documented, including a description of the content and origin of the practice, and why it is relevant not to reduce risk further. For risks that are lower than the generally acceptable level of risk, no further demonstration is necessary.

A.4 ALARP principle in Australia

1.4 Objects

(3) An object of these Regulations is to ensure that the risks to the health and safety of persons at facilities are reduced to a level that is as low as reasonably practicable

(6) An object of these Regulations is to ensure that the risks to the health and safety of persons who carry out diving to which the Act relates are reduced to a level that is as low as reasonably practicable.

Formal safety assessment

(2) The safety case for the facility must also contain a detailed description of the formal safety assessment for the facility, being an assessment, or series of assessments, conducted by the operator that:

(c) identifies the technical and other control measures that are necessary to reduce that risk to a level that is as low as reasonably practicable.

Safety management system

(3) The safety case for the facility must also contain a detailed description of the safety management system that:

(e) provides for the reduction to a level that is as low as reasonably practicable of risks to health and safety of persons at or near the facility including, but not limited to:

(i) risks arising during evacuation, escape and rescue in case of emergency; and

(ii) risks arising from equipment and hardware; and

Subdivision C Emergencies

2.16 Evacuation, escape and rescue analysis

(2) The evacuation, escape and rescue analysis must:

(h) identify, as a result of the above considerations, the technical and other control measures necessary to reduce the risks associated with emergencies to a level that is as low as reasonably practicable.

2.17 Fire and explosion risk analysis

(2) The fire and explosion risk analysis must:

(g) identify, as a result of the above considerations, the technical and other control measures necessary to reduce the risks associated with fires and explosions to a level that is as low as reasonably practicable.

4.4 Contents of DSMS

(2) A DSMS must provide for:

(e) the elimination of risks to persons involved with the project and associated work including:

(i) risks arising during evacuation, escape and rescue in case of emergency; and

(ii) risks to persons involved with the operation arising from equipment and hardware;

or the reduction of those risks to as low as reasonably practicable; and

4.19 Safety responsibilities of diving contractors

(1) A diving contractor must take all necessary steps to provide and maintain a working environment (including equipment and systems of work) that reduces risks to the safety

and health of divers and other members of the workforce to as low as reasonably practicable.

A.5 ALARP principle in Singapore

Chapter 7: ALARP Demonstration

7.1 Introduction

303 This technical guide has provided a broad overview on the concept of demonstration in Section 1.4. This chapter will further deal with ALARP demonstration in a safety case to ensure that risks arising from MAHs in MHIs are reduced to ALARP levels.

304 In a safety case, MHIs are required to show, through reasoned and supported arguments, that all practicable control measures that can be reasonably implemented have been implemented to reduce the risk for SCEs (i.e. all necessary measures). The adopted control measures for any identified SCE shall be shown to collectively eliminate or reduce the risk to health and safety to ALARP levels. The approach employed in providing evidence of ALARP demonstration within a safety case is at the MHI's discretion. In practice, a combination of approaches are likely to be necessary and this chapter attempts to provide clarity of the possible approaches while not limiting the possible options available for any MHI's ALARP demonstration.

305 It is expected that each MHI's safety case will be different, but each safety case has to feature ALARP demonstration. Sufficient information has to be provided to make the link between identified SCEs and ALARP demonstration of the control measures implemented to prevent major accidents or limit their consequences.

306 Risk Reduction Measures are control measures which includes both preventive and mitigative measures that are specific to the SCEs used in ALARP demonstration.

Appendix B Summary of ALARP regulation

	Norway	United Kingdom	Denmark	Australia	Singapore
The Term	Not Explicitly called ALARP/ALARA/SFARP	ALARP	ALARA/ALARP	ALARP	ALARP
The Scope	Apply to the petroleum activities at onshore facilities, other activities at onshore facilities and offshore petroleum activities. These regulations do not apply to Svalbard	Offshore installations or in connected activities	That the level must correspond to the level onshore means that the regulations according to the Working Environment Act are generally applied for regulation offshore, but special conditions offshore, both technical conditions and, with respect to mobile installations, international conditions, are also taken into account	(1) Other activities that cause vessels or structures to be facilities include activity categories (2) Categories of activities cause relevant vessels or structures to be defined as facilities	a). Descriptive aspects b). MAPP (Major Accident Prevention Policy) and SHMS (Safety & Health Management System), c). Predictive aspects d). Technical aspects e). Emergency response f). Assessment of ALARP.
Legally Binding	Physical person or body corporate, or several such persons or bodies corporate, holding a licence according to the Petroleum Act or previous legislation to carry out exploration, production, transportation or utilisation activities	The general provisions of the HSW Act and associated regulations such as the Management of Health and Safety at Work Regulations 1999 (SI 1999/3242) (MHSWR) and the Provision and Use of Work Equipment Regulations 1998 (SI 1998/2306) (PUWER) apply to all offshore employers, including those who are also duty holders under OSCR and the other offshore-specific regulations	The "Sole Concession of 8 July 1962" has a special status. The concession is held by A. P. Møller-Mærsk A/S and Mærsk Olie og Gas A/S, referred to as the "concession holders". The duties and responsibilities of the concessions holders are the same as those of the licensees	The requirements of these Regulations are in addition to the requirements imposed on a person by any other regulations made under the Act	This guide was jointly developed by the Safety Case Workgroup (SCWG) comprising representatives from the Major Hazards Department (MHD) and industry members of the Singapore Chemical Industry Council (SCIC). As well as all stakeholders in the MHI industry for feedback and support
Relation to Risk Acceptance Criteria	In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved.	122 The dark zone at the top represents an unacceptable region. For practical purposes, a particular risk falling into that region is regarded as unacceptable whatever the level of benefits associated with the activity. 123 The light zone at the bottom, on the other hand, represents a broadly acceptable region. Risks falling into this region are generally regarded as insignificant and adequately controlled.	Established quantitative (measurable) limit for the highest acceptable level of risk to perform an activity under normal operating conditions. The acceptance criteria are limits for when an activity may be carried out.	Risk is most commonly represented on an inverted triangle as increasing from a 'broadly acceptable' risk region, through a 'tolerable' region only if shown to be ALARP, to an 'intolerable' region, in which the risk cannot be justified on any grounds. Such diagrams also typically introduce numerical thresholds between the risk bands, often in terms of the Individual Risk Per Annum (IRPA) of a fatality. Operators may find it helpful to think of risk in terms of the inverted ALARP risk triangle; however it is important to be aware that the overall provisions the operator has to make through the safety case need to consider hazards and risks in all regions of the triangle.	3.3 Under the Safety Case regime, MHIs are required to perform ALARP demonstration for SCEs. By establishing a single scenario risk target, MHIs will be able to evaluate the risk of each SCE and determine, through the implementation of adequate and robust barriers, whether the risk is reduced to ALARP.
To what extent does ALARP mean to use cost benefit analysis?	• Determine optimum level of safety protection when risk acceptance criteria have been satisfied through prior risk assessment. Usually this will imply that risk acceptance criteria for personnel (possibly also environment) have been satisfied, and that the CBA is used in order to find the optimum level of protection against material damage risk. (Type I). • Determine what is acceptable risk level without prior satisfaction of risk acceptance criteria. If this is the case, usually the same approach is then applied to risk to personnel, risk to environment and risk to assets, which all then are evaluated within an ALARP context. (Type II). • Determine optimum level of emergency preparedness when risk acceptance criteria and functional requirements to emergency preparedness have been satisfied through prior risk assessment and emergency preparedness analysis. (Type III).	Cost-Benefit Analysis aids the decision-making process by giving monetary values to the costs and benefits and to enable a comparison of like quantities. The analysis can help make an informed choice between risk reduction options. A Cost-Benefit Analysis cannot form the sole argument of an ALARP decision nor can it be used to undermine existing standards and good practice	Where the costs are grossly disproportionate to the additional risk reduction achieved by means of the risk reduction measures, the risk reduction measures may be omitted	Cost benefit analysis [CBA] – the numerical assessment of the costs of implementing a design change or modification and the likely reduction in fatalities that this would be expected to achieve. The quality of the modelling and the data will affect the robustness of the numerical estimate and the uncertainties in it must always be borne in mind when using the estimate in risk management decisions. In making this assessment there is a need to set criteria on the value of a life or implied cost of averting a statistical fatality (ICAF). In reality of course there is no simple cut-off and a whole range of factors, including uncertainty need to be taken into account in the decision-making process.	Cost benefit analysis (CBA) – the numerical assessment of the costs of implementing a design change or modification and the likely reduction in risk that this would be expected to achieve. CBA may be used in cases where it is difficult to determine whether the cost is justified after completing risk assessments of sufficient rigour. The UK HSE website provides an in-depth explanation on the uses and limitations of using CBA for ALARP decision making. MHIs (Major Hazard Installations) using CBA shall ensure that all data and assumptions are justified in the safety case.