UKOPA

United Kingdom Onshore Pipeline Operators' Association

Good Practice Guide

Application of cost benefit analysis to demonstrate ALARP

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The guidance in this document identifies what is considered by UKOPA to represent current UK pipeline industry good practice within the defined scope of the document. All requirements should be considered guidance and should not be considered obligatory against the judgement of the Pipeline Owner/Operator. Where new and better techniques are developed and proved, they should be adopted without waiting for modifications to the guidance in this document.

Comments, questions and enquiries about this publication should be directed to**:**

UK Onshore Pipeline Operators' Association
Pipeline Maintenance Centre
Ripley Road
Ambergate
Derbyshire
DE56 2FZ

E-mail: enquiries@ukopa.co.uk

Website: www.UKOPA.co.uk

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1. EXECUTIVE SUMMARY

Pipeline operators operating Major Accident Hazard Pipelines (MAHPs) are required to demonstrate that risks from their pipelines are ‘as low as reasonably practicable’ (ALARP). For pipelines, demonstration of this generally requires compliance with recognised industry good practice, supported where necessary by risk analysis. In circumstances where the risk to people adjacent to pipelines exceeds broadly acceptable limits, risk reduction measures need to be considered.

The United Kingdom (UK) Health and Safety Executive (HSE) have outlined how they expect such cases to be considered using cost benefit analysis. This guide describes how the cost benefit methodology is applied to risk reduction measures for pipeline operations and provides examples. It also describes how the methodology is applied in the Republic of Ireland to meet the requirements of the Commission for Regulation of Utilities (CRU) (formerly the Commission for Energy Regulation (CER)) and draws, where appropriate, on guidance provided by the CRU.

2. OBJECTIVES/SCOPE OF GUIDANCE

Pipeline operators are required to demonstrate that the risks associated with their activities are ‘as low as reasonably practicable’ (ALARP). There are typically three aspects to an ALARP demonstration:

1. Demonstrating that relevant industry standards, codes and good practice have been / are being followed in the design, construction, operation and maintenance of the pipeline.

2. Highlighting where additional measures have been implemented to reduce risk.

3. Identifying additional risk reduction measures that could be considered and performing a cost benefit analysis to determine whether the cost of implementing a measure is commensurate with the safety benefit experienced.

Steps 1 and 2 are beyond the scope of this document. The objectives of this guidance are to explain why and how the concept of ALARP is implemented by pipeline operators, and in particular, how cost benefit analysis is applied to demonstrate that risks associated with pipeline operations are ALARP.

3. INTRODUCTION

3.1 The concept of reasonable practicability

The concept of what is 'reasonably practicable' was first considered by the Court of Appeal of England and Wales in the case of Edwards v National Coal Board 1942 [1], where the Court of Appeal 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*"

> "*'Reasonably practicable' is a narrower term than 'physically possible', and seems to me to imply that a computation must be made by the owner in which the quantum of risk is placed on one scale and the sacrifice involved in the measures necessary for averting the risk (whether in money, time or trouble) is placed in the other, and that, if it be shown that there is a gross disproportion between them - the risk being insignificant in relation to the sacrifice - the defendants discharge the onus on them*."

In dealing with the concept of what is reasonably practicable, the CRU guidance on ALARP in Ireland [2] suggests the following approach:

- First, the onus of proving that all that is reasonably practicable has been done lies on the duty holder;
- second, the duty is higher than the common law duty of care; and
- third, cost is not always to be a factor in determining whether reasonably practicable precautions have been taken, but equally a balance has to be considered between the risk removed by a particular precaution and any risk created by the implementation of that measure.

The courts have accepted that in applying the ALARP principle, a risk reduction measure must be adopted unless the sacrifice involved in implementing that measure is grossly disproportionate to the risk reduction gained (grossly disproportionate is explained in section 5.1). The ALARP principle arises from the fact that boundless time, effort and money could be spent in the attempt to reduce a risk to zero and so some limit must be placed on how far a duty holder must go to discharge their duty, otherwise economic activity would cease; this limit is defined to be one of reasonable practicability. What is reasonably practicable in any given situation will be determined by the facts of the case.

3.2 Obligation to ensure risks are ALARP

The fundamental obligation under the law is for a duty holder to reduce all safety risks to a level that is ALARP. It is based on the principle that those who create and have control over risks have responsibility for their management and must actively assess them to ensure that risk reduction measures are implemented so that the residual risk is ALARP.

Regulation 23 of the Pipelines Safety Regulations [3] for the major accident prevention document (MAPD) has a requirement for an ALARP demonstration on those operating major accident hazard pipelines (MAHPs) as follows.

Paragraph (1) states:

> *(1) “The operator shall, before the design of a major accident hazard pipeline is completed prepare, and thereafter revise or replace as often as may be appropriate, a document relating to the pipeline containing, subject to paragraph (2), sufficient particulars to demonstrate that -*
>
> *(a) all hazards relating to the pipeline with the potential to cause a major accident have been identified;*
>
> *(b) the risks arising from those hazards have been evaluated;*
>
> *(c) the safety management system is adequate; and*
>
> *(d) he has established adequate arrangements for audit and for the making of reports thereof.”*

Paragraph (4) states:

> *(4) “In this regulation..."safety management system" means the organisation, arrangements and procedures established by the operator for ensuring that the risk of a major accident is as low as is reasonably practicable.”*

4. ALARP PRINCIPLES

4.1 Overview of the ALARP principle

The fundamental principle of risk-based hazard management is that whilst risks cannot always be completely eliminated, it should be possible to reduce them to a level that is ALARP, so that they are tolerable to society because all reasonably practicable risk reduction measures have been implemented. The management of hazards, such that the safety risks are ALARP, must be demonstrated, and for MAHPs the mechanism for such a demonstration is through the MAPD.

The ALARP principle is illustrated in Figure 1. The triangle represents an increasing level of cumulative risk (all risks, or the total risk, that a person, or population is exposed to) from a low risk, represented by green at the base of the triangle, to a high risk, represented by red at the top of the triangle.

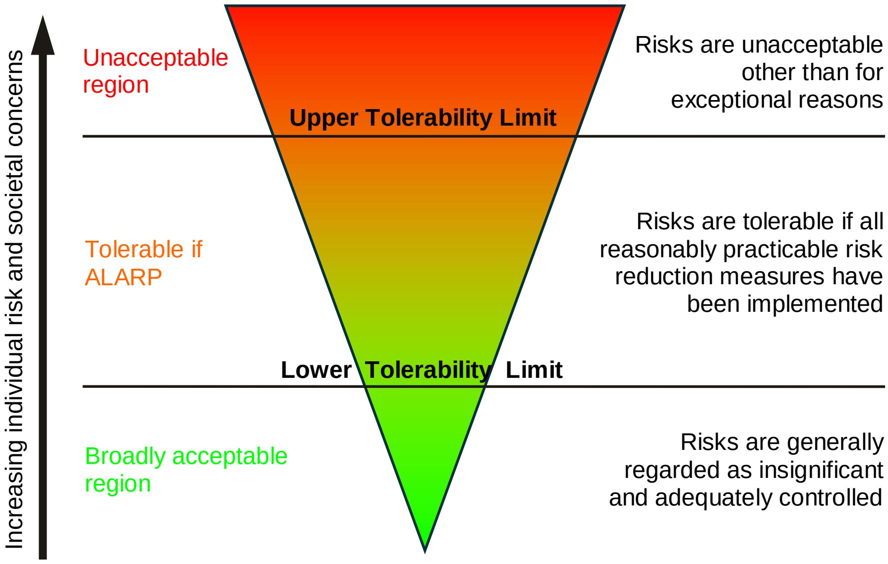


Figure 1: Schematic diagram illustrating the ALARP principle

Three regions of risk are represented:

- **Unacceptable Region**

  Above the Upper Tolerability Limit, the risks are in the unacceptable region. Operations with risks falling in this region would be regarded as intolerable unless the risk level can be reduced or would only be permitted for exceptional reasons.

- **Broadly Acceptable Region**

  Below the Lower Tolerability Limit is the 'broadly acceptable' risk region. Risks falling into this region are considered tolerable to society and comparable to everyday risks faced by the general public. For operations with risk levels in this region, the ALARP demonstration is likely to be straightforward and based on adherence to relevant codes, standards and established good practice. Further action to reduce risks is not usually required unless reasonably practicable measures are available.

- **'Tolerable if ALARP' Region**

  Where the risk level falls between the Upper Tolerability Limit and the Lower Tolerability Limit, the risk is only tolerable if it is ALARP and a case-specific ALARP demonstration is required. This must show that current good practice has been followed and that all reasonably practicable risk reduction measures have been identified and implemented, determined, for example, through the use of cost benefit analysis.

  The term 'reasonably practicable' indicates a narrower range than all physically possible risk reduction measures. If the cost of a risk reduction measure, whether in terms of money, time or trouble, can be demonstrated to be grossly disproportionate to the risk reduction gained from the measure, taking account of the likelihood and degree of harm presented by the hazard, then it may not be required to implement the measure. The higher the initial level of risk, the greater the degree of rigour that is required to show that those risks have been reduced to ALARP.

  The risks should be periodically reviewed to ensure that they still meet the ALARP criteria, for example, by ascertaining whether further or new control measures need to be introduced to take into account changes over time, such as new knowledge about the risk or the availability of new techniques for reducing or eliminating risks.

4.2 Individual Risk

Tolerability limits for individual risk are based on the risk of death per year and are defined by the UK Health and Safety Executive (HSE) [4] to be:

- Lower Tolerability Limit for the public and workers - 1×10^{-6} per year
- Upper Tolerability Limit for the public - 1×10^{-4} per year
- Upper Tolerability Limit for workers - 1×10^{-3} per year

However, for the operation of MAHPs, individual risk levels are rarely an issue on their own, as conditions that give rise to higher levels of individual risk also give rise to societal risk concerns and it is these that play a greater role in determining whether or not a risk is tolerable.

4.3 Societal Risk

Societal risk, defined as the relationship between the frequency of an incident and the number of casualties that may result, is usually expressed in the form of an 'FN curve'. This is a graph showing the cumulative frequency, F, with which N or more casualties are produced, plotted against N[1]. The calculated societal risk is assessed against risk tolerability criteria in the form of a societal risk criterion FN curve.

For application to pipelines, it is necessary to specify a length over which the frequency and consequences of the accident scenarios are evaluated. For natural gas MAHPs, it is recommended that the societal risk criterion detailed in the IGEM Standard IGEM/TD/1 is applied, which is based on a one-mile length of pipeline [7]. For steel pipelines transporting

[1] The calculation of N depends on the harm criteria applied to the effects of the release. Generally, a 'casualty' is defined as a person who becomes a fatality or receives life-changing injuries. See IGEM/TD/2 [5] or PD8010 Part 3 [6] for further details.

other substances, the British Standard PD8010 is recommended, which contains societal risk criteria based on a one-kilometre length of pipeline [6].

4.4 Risk Management Process

In carrying out an ALARP assessment, a risk management process (also termed hazard management process) should be followed that incorporates the ALARP principle.

An example of the steps taken in such a process is given below [2] (a flowchart can also be found in the same document).

1. A comprehensive identification of all hazards associated with the activity including specific identification of any major accident hazards (MAHs) - note similar requirements apply to MAHPs as defined by the Pipeline Safety Regulations 1996.

2. Where good practice exists, this or its equivalent must be implemented.

3. If there are MAHs associated with the activity:

    a) A quantitative assessment of the cumulative safety risk associated with the activity must be carried out, considering both MAH and non-MAH but with specific assessment of the MAH(s).

    b) Compare the cumulative risk from all hazards to the Upper and Lower Tolerability Limits:

        - If the cumulative risk is above the Upper Tolerability Limit (i.e. is intolerable), the activity is not permitted without immediate risk reduction. This is unlikely for pipeline risks.

        - If the cumulative risk is below the Lower Tolerability Limit, demonstrate that relevant good practice has been identified and implemented and that arrangements are in place (including periodic review) to ensure on-going compliance.

        - If the cumulative risk is between the Upper and Lower Tolerability Limits, identify a range of appropriate risk reduction measures:

            - Implement each risk reduction measure unless it is demonstrated and documented that it is not reasonably practicable to do so, and

            - if the safety benefit of a risk reduction measure cannot be assessed with sufficient certainty to determine if it is reasonably practicable, recourse must be made to the precautionary principle (see [4]). This ensures that a lack of certainty is not a sufficient reason for not taking preventive action.

4. If there are no MAHs associated with the activity:

    a) A suitable and sufficient assessment of the risks associated with the activity must be carried out, which is likely to be qualitative or semi-quantitative and direct comparison with the Risk Tolerability Limits is not required. Then:

    b) Identify any further risk reduction measures that could be implemented; and

c) Implement those risk reduction measures which are required by good practice, plus any others which are reasonably practicable.

5. Ensure that all risks continue to be ALARP throughout the lifecycle of the infrastructure or activity by periodic review following this process.

5. METHODOLOGY FOR COST BENEFIT ANALYSIS

5.1 Overview of Methodology and Criteria

The recommended methodology for undertaking cost benefit analysis as part of an ALARP demonstration follows the approach set out by the HSE [4], [8].

The methodology is based on a comparison of:

a) The Value of Preventing a Fatality (VPF), as described in Section 0

b) The Cost of Preventing a Fatality (CPF), as described in Section 5.3

The ratio of these two costs, CPF / VPF, is the Proportion Factor (PF).

If the Proportion Factor for a risk reduction measure is calculated to be higher than a defined value, then the costs are said to be ‘grossly disproportionate’ to the benefit achieved and implementation of the measure would not be reasonably practicable.

Judgement on when the degree of disproportion can be considered ‘gross’ (and hence the choice of the limiting value for the Proportion Factor) depends on the levels of individual and societal risks (and possibly the societal concern in certain circumstances) and is made on a case-by-case basis. The minimum value of the Proportion Factor must be 1, since a value of less than 1 implies a bias against safety and in such cases the safety measure must be implemented even when the risks are close to being broadly acceptable. It is also the case that the limiting value of the Proportion Factor will increase as the risk increases; that is, it is expected that more would be spent to reduce risks by a given amount if the initial risk level is at the upper limit of the ALARP region than if the risks lie close to the broadly acceptable region.

There is no authoritative guidance as to what factors should be taken into account in determining whether cost is grossly disproportionate. UKOPA recommends that a minimum Proportion Factor of 10 is used unless member companies have previously established their own values.

5.2 Derivation of Value of Preventing a Fatality (VPF)

HSE’s publication ‘Reducing Risks, Protecting People’ [4] paragraph 103 states:

> *“When an option produces the benefit of preventing fatalities, this requires putting a monetary value on achieving a reduction in the risk of death. For example, for the purpose of conducting CBAs, we currently take as a benchmark that the value for preventing a fatality (VPF) is about £1 000 000 (2001 figure). This figure derives from the value used by the Department of Transport, Local Government and the Regions (DTLR) for the appraisal of new road schemes.”*

Inflated to current (2018) values based on Retail Price Index, the current value for VPF is £1.6m. Note that this figure should be treated as a minimum VPF and individual operators may choose to apply a higher value.

5.3 Derivation of Cost of Preventing a Fatality (CPF)

To obtain the CPF for a specific risk reduction measure, the following factors need to be obtained:

a) An estimate of the safety risk before the risk reduction measure is implemented

b) An estimate of the safety risk after the risk reduction measure is implemented

c) The annualised cost of the risk reduction measure

For a pipeline, individual risk cost benefit analysis based on a single event is not usually undertaken, so societal risk assessment (risk to an exposed population within the hazard distances from all events from a specified length of pipeline) is used to obtain an 'Expectation Value', equal to the expected number of casualties per year. It is calculated by summing the product of the frequency of each failure scenario with the number of predicted casualties, across all hazardous scenarios considered.

The CPF is then obtained as:

$$CPF = \text{Annualised Cost of Risk Reduction} / (E_{before} – E_{after})$$

where E_{before} is the Expectation Value before the risk reduction measure is implemented and E_{after} is the Expectation Value after the risk reduction measure is implemented.

The annualised cost of the risk reduction measure is obtained for capital items by dividing the capital cost by the expected future life of the asset with risk reduction implemented. Any annual costs (e.g. cost of extra pipeline surveillance) is added to the annualised capital cost to obtain the total annualised cost. For pipelines, an expected future life of around 40 years is typically assumed if there is no other information available.

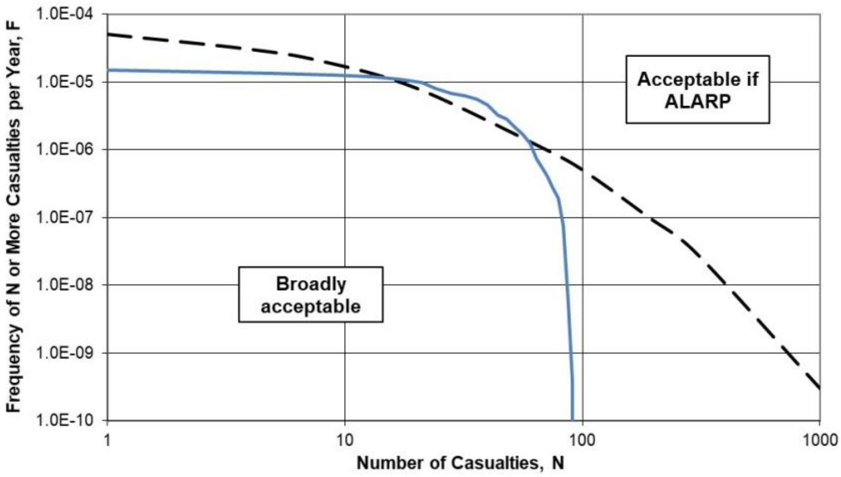
Consideration should be given to the most cost-effective implementation of potential risk reduction measures, for example by applying pipeline protection to those areas that contribute most to the risk.

5.4 Cost Benefit Analysis as applied in Republic of Ireland

The methodology for applying cost benefit analysis in the Republic of Ireland has been defined by the Commission for Regulation of Utilities (CRU) (formerly the Commission for Energy Regulation (CER)) and is mandatory for use [2]. It follows the same procedure as described above, but the terminology and VPF equivalent is different. The methodology is described in Appendix A.

6. COST BENEFIT EXAMPLES

6.1 Example 1



A societal risk FN curve for a section of pipeline within a populated suburban area, shown above as the blue line, lies above the IGEM/TD/1 societal risk criterion line (black dotted line) [7] and is therefore in the ALARP region and risk reduction measures should be considered. In this case, the cost benefits of increasing surveillance on the pipeline and laying concrete slabbing are considered.

Increased Surveillance

Expectation Value before risk reduction, $E_{before} = 4.41 \times 10^{-4}$ per year.

Expectation Value with twice weekly surveillance, which then reduces the risk to below the IGEM/TD/1 criterion line, $E_{after} = 1.77 \times 10^{-4}$ per year.

$$\Delta E = E_{before} – E_{after} = 4.41 \times 10^{-4} - 1.77 \times 10^{-4} = 2.64 \times 10^{-4} \text{ per year.}$$

Typical cost of extra surveillance is calculated as follows:

- Patrol vehicle cost £30,000, 1% extra usage over 5 years' life, annual cost £60
- 2 technicians to patrol an extra 1 hour per week, 2 man-hours per week @ £15 per hour, annual cost £1,560
- Total annualised cost of risk reduction = £1,620 per year.

Cost of Preventing a Fatality, CPF = Annualised Cost of Risk Reduction / (E_{before} – E_{after})

= £1620 / 2.64×10^{-4}

= £6.14 million

VPF = £1.6 million

Therefore, Proportion Factor = CPF / VPF = £6.14 million / £1.6 million = 3.8.

Concrete Slabbing

Expectation Value before risk reduction, $E_{before} = 4.41 \times 10^{-4}$ per year.

Expectation Value with concrete slabbing, which then reduces the risk to below the IGEM/TD/1 criterion line, $E_{after} = 7.68 \times 10^{-5}$ per year.

$$\Delta E = E_{before} - E_{after} = 4.41 \times 10^{-4} - 7.68 \times 10^{-5} = 3.65 \times 10^{-4} \text{ per year.}$$

For installing concrete slabbing, a total of approximately 100m of slabbing is required for this suburban pipeline, at a typical cost of £1,000 per metre, giving a total cost of £100,000. If this is discounted over 40 years (typical assumption for a pipeline), the total annualised cost is £100,000 / 40 = £2,500 per year.

Cost of Preventing a Fatality, CPF = Annualised Cost of Risk Reduction / ($E_{before} - E_{after}$)

= £2500 / 3.65 x 10^{-4}

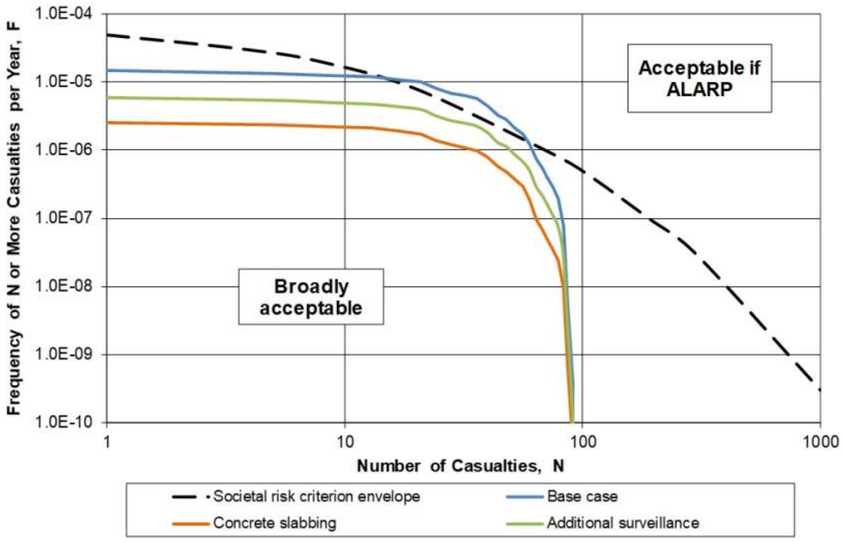
= £6.86 million

VPF = £1.6 million

Therefore, Proportion Factor = CPF / VPF = £6.86 million / £1.6 million = 4.3

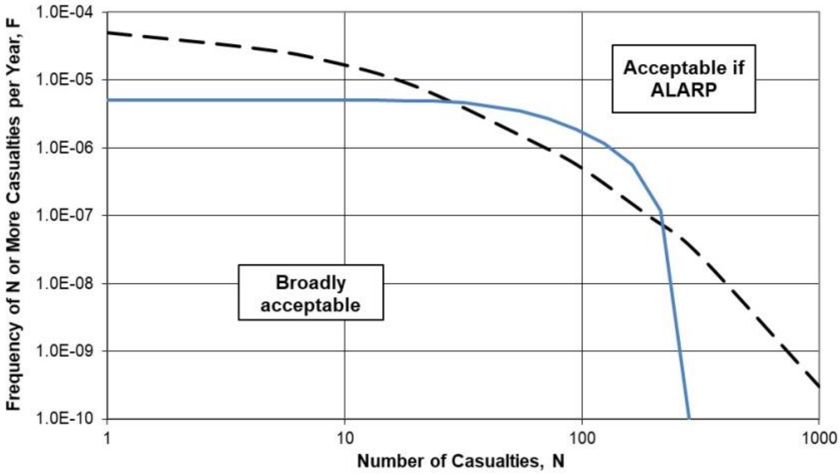
Summary

The FN curves for the base case and the two risk reduction measures considered are shown in the figure below.



In this case, the Proportion Factors are such that the costs would not be considered grossly disproportionate to the benefits achieved and so the risks associated with the existing pipeline are not considered to be ALARP. Further consideration may be given to which risk reduction measure should be implemented, or a combination of risk reduction measures may be appropriate.

6.2 Example 2



A societal risk FN curve for a section of pipeline within a rural area, shown above as the blue line, lies above the IGEM/TD/1 societal risk criterion line (black dotted line) [7] and is therefore in the ALARP region and risk reduction measures should be considered. In this case, the cost benefits of laying concrete slabbing and relaying the pipeline with thick-walled pipe are considered.

Concrete Slabbing

Expectation Value before risk reduction, $E_{before} = 4.31 \times 10^{-4}$ per year.

Expectation Value with concrete slabbing, which then reduces the risk to below the IGEM/TD/1 criterion line, $E_{after} = 4.42 \times 10^{-5}$ per year.

$$\Delta E = E_{before} – E_{after} = 4.31 \times 10^{-4} – 4.42 \times 10^{-5} = 3.87 \times 10^{-4} \text{ per year.}$$

For installing concrete slabbing, a total of approximately 250m of slabbing is required for this pipeline, at a typical cost of £1,000 per metre, giving a total cost of £250,000. If this is discounted over 40 years (typical assumption for a pipeline), the total annualised cost is £250,000 / 40 = £6,250 per year.

Cost of Preventing a Fatality, CPF = Annualised Cost of Risk Reduction / ($E_{before} – E_{after}$)

= £6250 / 3.87×10^{-4}

= £16.16 million

VPF = £1.6 million

Therefore, Proportion Factor = CPF / VPF = £16.16 million / £1.6 million = 10.1

Relaying with thick-walled pipe

Expectation Value before risk reduction, $E_{before} = 4.31 \times 10^{-4}$ per year.

Expectation Value with concrete slabbing, which then reduces the risk to below the IGEM/TD/1 criterion line, $E_{after} = 2.96 \times 10^{-5}$ per year.

$\Delta E = E_{before} - E_{after} = 4.31 \times 10^{-4} - 2.96 \times 10^{-5} = 4.01 \times 10^{-4}$ per year.

For relaying with thick-walled pipe, a total of approximately 250m of pipe requires replacement. At a typical cost of £2,000 per metre, plus fixed costs of £200,000 for putting in a temporary pipeline diversion, this gives a total cost of £700,000. If this is discounted over 40 years, the total annualised cost is £700,000 / 40 = £17,500 per year.

Cost of Preventing a Fatality, CPF = Annualised Cost of Risk Reduction / ($E_{before} - E_{after}$)

= £17500 / 4.01×10^{-4}

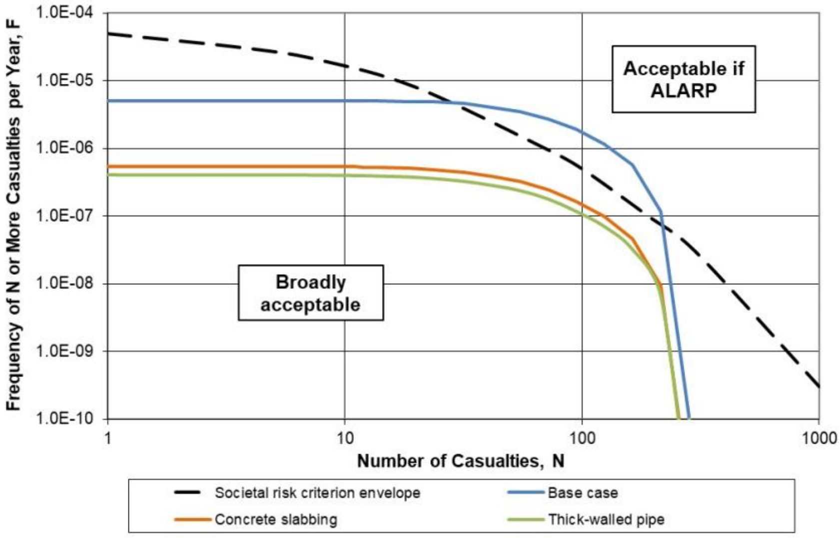
= £43.60 million

VPF = £1.6 million

Therefore, Proportion Factor = CPF / VPF = £43.60 million / £1.6 million = 27.2

Summary

The FN curves for the base case and the two risk reduction measures considered are shown in the figure below.



In this case, the Proportion Factor of 27.2 for relaying 250m of pipeline with thick-walled pipe is considered 'grossly disproportionate' to the safety benefit achieved and is therefore not justifiable.

For installation of concrete slabbing, the Proportion Factor of 10.1 is borderline as to whether the costs would be considered to be 'grossly disproportionate'. In this case, the operator should review all assumptions to ensure that they are adequate and conservative towards safety. If this is the case, then a decision may be made that the installation of any additional safety measures is not justifiable and the residual risk would be considered to be ALARP.

NOTE: all costs and frequencies quoted in these examples are fictional and should not be used in real assessments.

7. REFERENCES

[1] Edwards v. The National Coal Board [1949] 1 KB 704; [1949] 1 All ER 743.

[2] 'ALARP Guidance – Part of the Petroleum Safety Framework and the Gas Safety Regulatory Framework', CER Commission for Energy Regulation, Policy Document, CER/16/106, 29 March 2016, Version 3.0.

[3] 'A Guide to the Pipelines Safety Regulations 1996 Guidance on Regulations', first published 1996, ISBN 978 0 7176 1182 9, obtainable from http://www.hse.gov.uk/pUbns/priced/l82.pdf.

[4] 'Reducing Risks, Protecting People: HSE's decision-making process' first published 2001, ISBN 0 7176 2151 0, obtainable from http://www.hse.gov.uk/risk/theory/r2p2.htm.

[5] 'Assessing the risks from high pressure natural gas pipelines' IGEM/TD/2 Edition 2, Institute of Gas Engineers and Managers, Communication 1764, 2013.

[6] 'Code of Practice for Pipelines - Part 3: Steel Pipelines on Land - Guide to the Application of Pipeline Risk Assessment to Proposed Developments in the vicinity of Major Accident Hazard Pipelines containing Flammables - Supplement to PD 8010-1:2004', British Standards Institute, PD 8010 3:2009+A1:2013.

[7] 'Steel pipelines and associated installations for high pressure gas transmission', IGEM/TD/1 Edition 5 with Amendments, Institute of Gas Engineers and Managers, Communication 1789, 2016.

[8] 'Guidance on ALARP Decisions in COMAH', SPC/Permissioning/37, first issued in 2001 as SPC 12, obtainable from: http://www.hse.gov.uk/foi/internalops/hid_circs/permissioning/spc_perm_37/.

[9] 'HSE Principles for Cost Benefit Analysis (CBA) in Support of ALARP Decision', HSE, obtainable from http://www.hse.gov.uk/risk/theory/alarpcba.htm.

8. GLOSSARY OF TERMS AND ABBREVIATIONS

ALARP	As Low as Reasonably Practicable
CBA	Cost Benefit Analysis
CER	Commission for Energy Regulation
CPF	Cost of Preventing a Fatality
DTLR	Department of Transport, Local Government and the Regions
CRU	Commission for Regulation of Utilities
GDF	Gross Disproportion Factor
HSE	Health and Safety Executive
ICAF	Implied Cost of Averting a Fatality
IGEM	Institute of Gas Engineers and Managers
MAH	Major Accident Hazard
MAHP	Major Accident Hazard Pipeline
MAPD	Major Accident Prevention Document
NRA	National Roads Authority
PF	Proportion Factor
PLL	Potential Loss of Life
VPF	Value of Preventing a Fatality

APPENDIX A COST BENEFIT ANALYSIS AS APPLIED IN REPUBLIC OF IRELAND

The methodology for applying cost benefit analysis in the Republic of Ireland has been defined by the Commission for Regulation of Utilities (CRU) (formerly the Commission for Energy Regulation (CER)) and is mandatory for use [2].

Extra expenditure for risk reduction measures is considered justifiable if the cost is not 'grossly disproportionate' when compared with the benefit achieved by the risk reduction measures. The CRU guidance details a 2-stage process:

1. Calculate the Implied Cost of Averting a Fatality (ICAF) for the risk reduction measure, which is the cost of the risk reduction measure divided by the risk reduction achieved (the reduction in Potential Loss of Life over the lifetime of the risk reduction measure)

2. Compare this to a Defined ICAF criterion.

A risk reduction measure will then be reasonably practicable to implement unless:

- The Calculated ICAF is grossly disproportionate to the Defined ICAF.

For the purposes of the ALARP assessment the CRU advise that a Defined ICAF of at least €2,500,000 is used (based on 2015 data). This value is based on a determination made by the National Roads Authority (NRA), which is the only comparable figure that the CRU has found employed by another statutory agency in Ireland. The NRA has calculated accident costs and at resource costs (2009 prices and values) the cost per fatality was calculated at €2,060,099 which is €2,500,000 in (index-linked) 2015 prices.

Therefore, to calculate the Implied Cost of Averting a Fatality (ICAF)

1. Assess risk reduction measure to obtain cost.

2. Decide how many more years the risk reduction measure will apply for capital items.

3. Calculate the reduction in Potential Loss of Life (PLL) resulting from this risk reduction measure. Thus;

$$\text{Implied Cost of Averting a Fatality (ICAF)} = \frac{\text{Cost of risk reduction measure}}{\text{Lifetime (years) X PLL reduction}}$$

The calculated ICAF is then compared with the Defined ICAF criterion to obtain the Gross Disproportion Factor:

Gross Disproportion Factor (GDF) = Calculated ICAF / Defined ICAF criterion

For a risk reduction measure to be judged as not reasonably practicable (grossly disproportionate), a GDF of at least 2 is essential and a robust justification is required for any value less than 10.