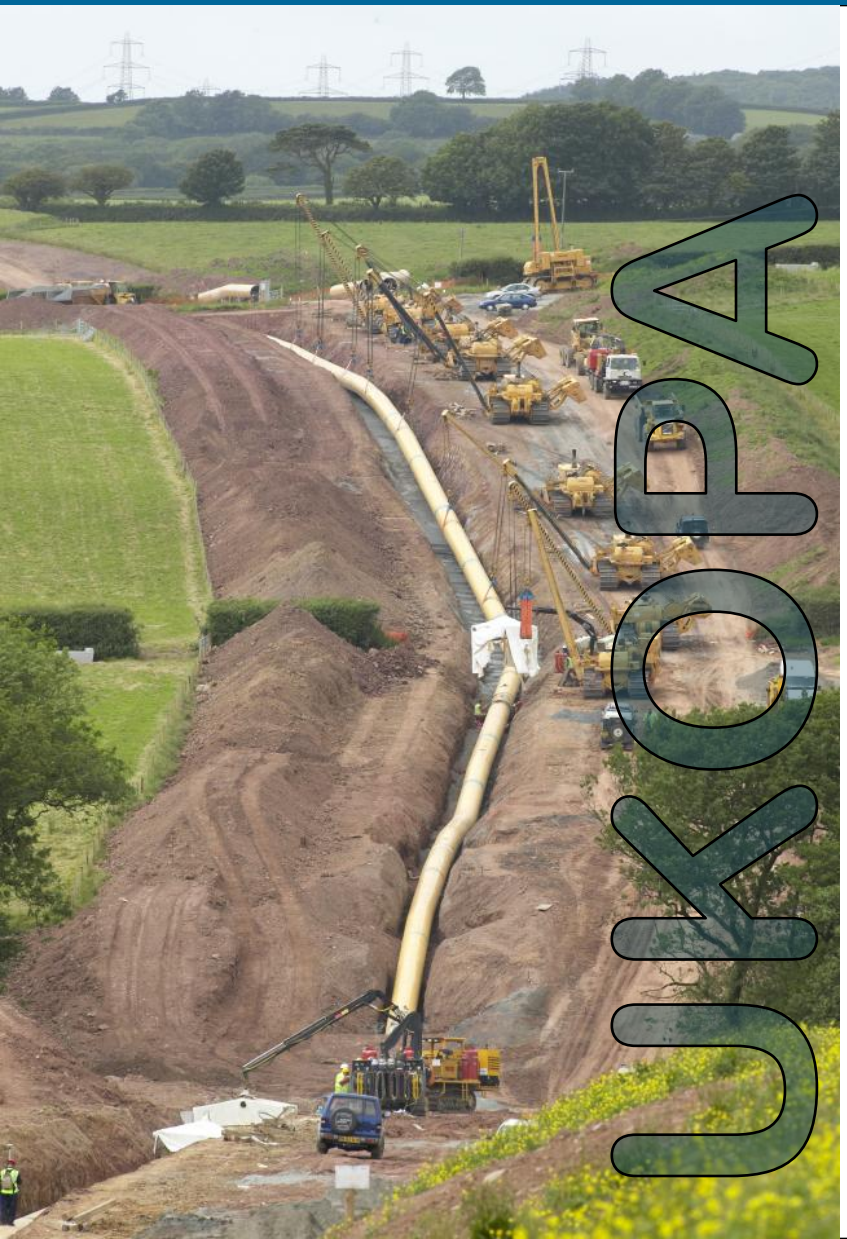

Use of Cost Benefit Analysis to Demonstrate ALARP

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- Background
- ALARP Principle
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Good Practice Guide – Use of CBA to Demonstrate ALARP

- 1st Draft developed by Rod McConnell
  - Issued to FARWG for comment on 1st September 2017
  - Significant comments from DNV GL (7/9/17)
  - Additional comments from Richard Price (BPA) (11/9/17)
- FARWG meeting 12th September 2017
  - Actioned Mike Acton (DNV GL) to produce 2nd draft
  - Requested members not to comment until 2nd draft issued
- Deadline for 2nd draft – end of Q1 2018

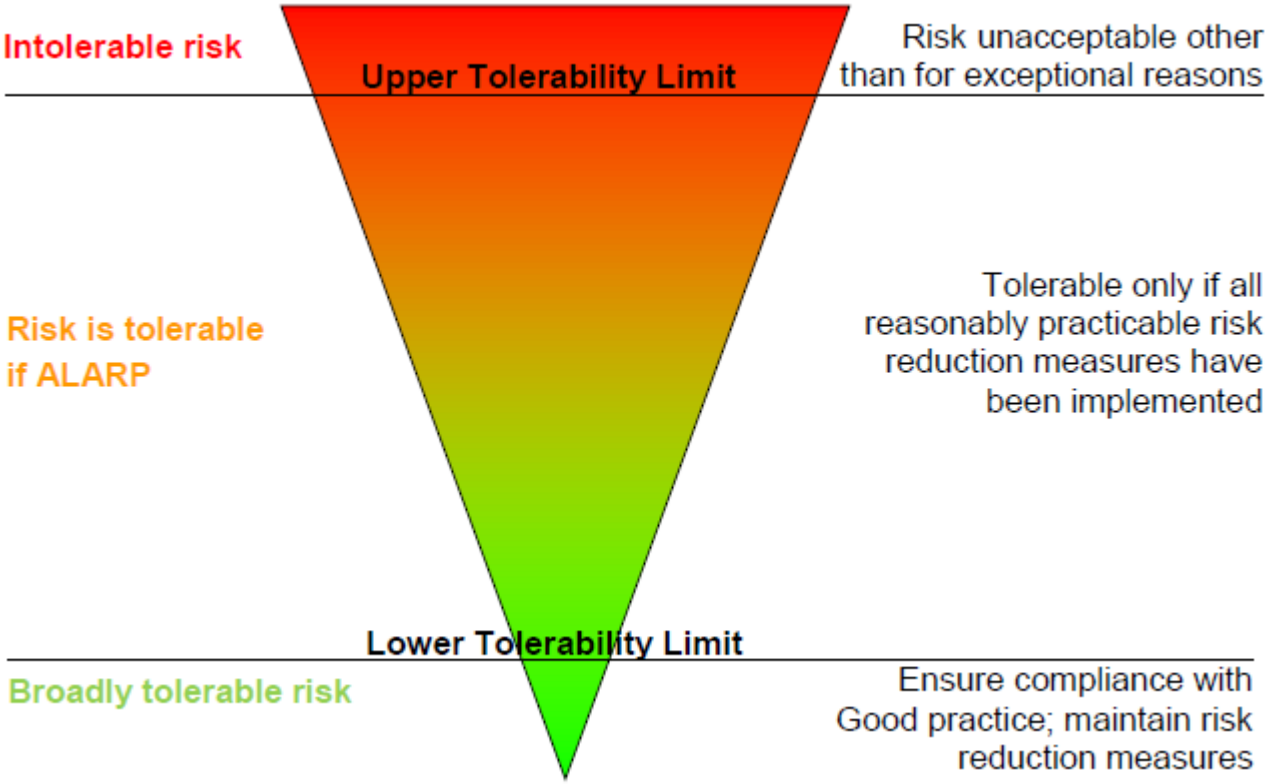
Background – ALARP Principle

- Concept of ALARP introduced in Appeal Court judgement from Edwards vs National Coal Board, [1949] 1 All ER 743

"'Reasonably practicable' is a narrower term than 'physically possible' … 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."

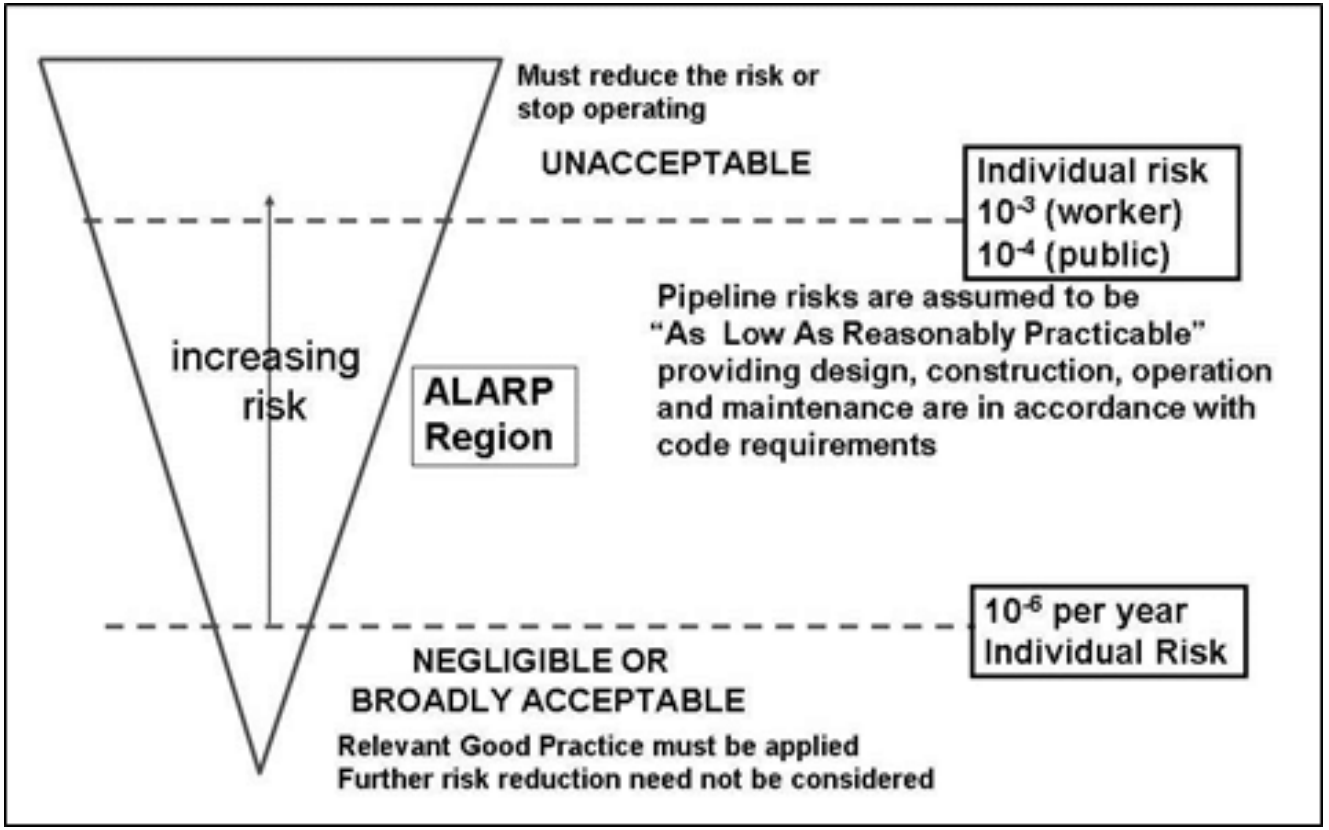
- In Ireland, definition of reasonably practicable is the same
  - Boyle vs Marathon Petroleum (Irl) Ltd [1999] 2 I.R. 460 at the Supreme Court

ALARP Principle – CER



- Residual risk should be reduced so far as is reasonably practicable

ALARP Principle – HSE



- Residual risk should be reduced so far as is reasonably practicable

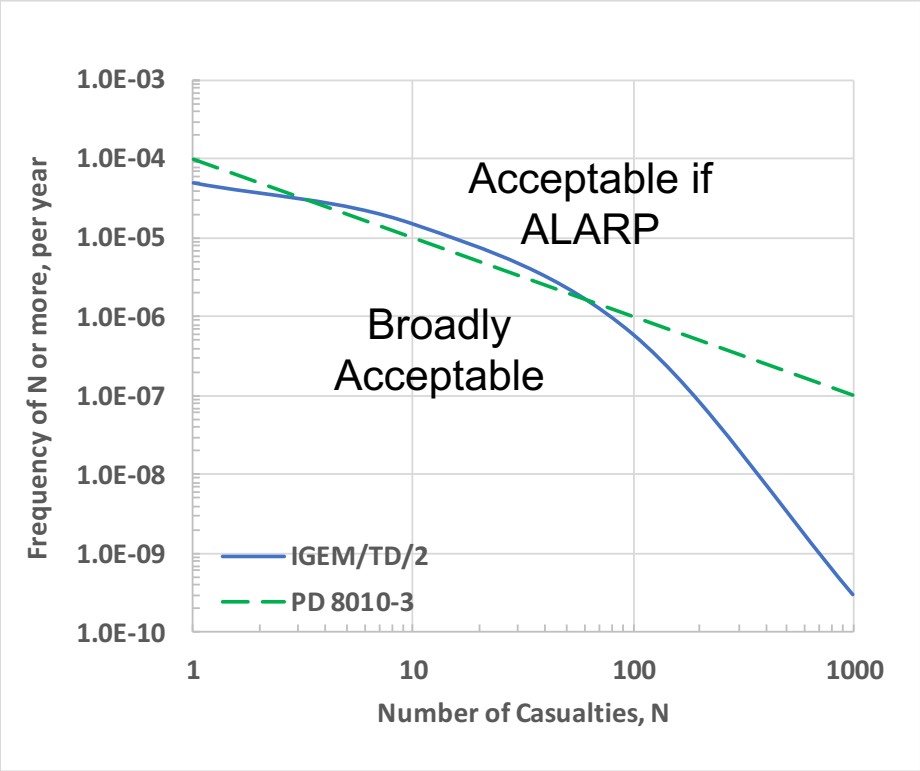
Tolerability Limits – Individual Risk

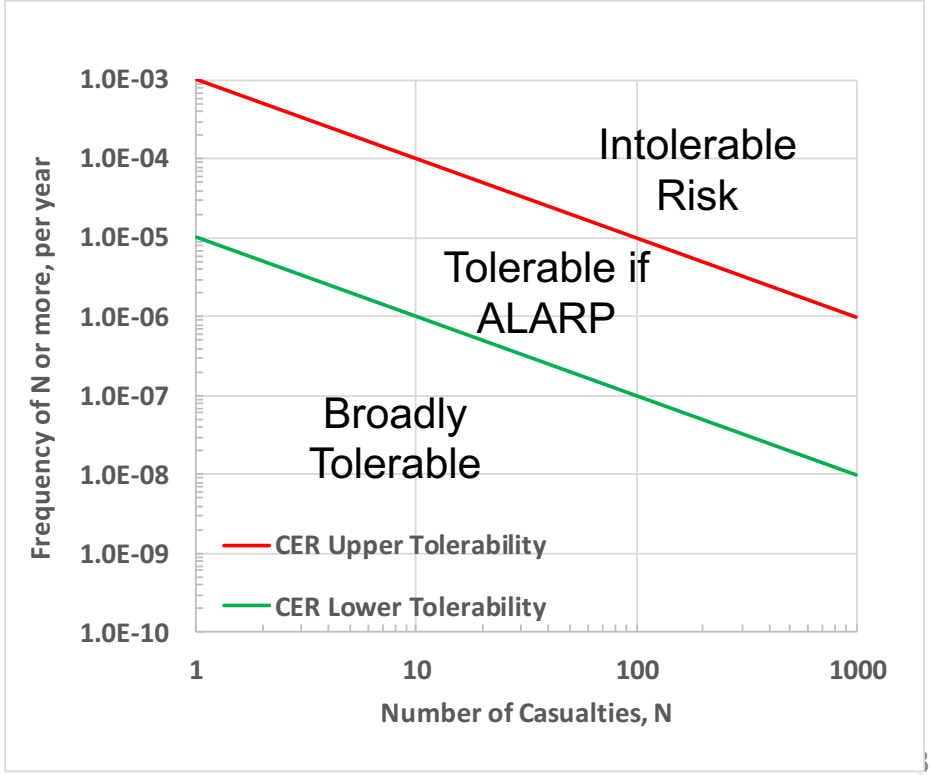
- UK HSE & ROI CER
  - Upper Tolerability Limit (Worker) – 1×10^{-3} per year
  - Upper Tolerability Limit (Public) – 1×10^{-4} per year
  - Lower Tolerability Limit – 1×10^{-6} per year

- Average risk of death from all causes is approximately 1×10^{-2} per year
  - Risks at lower tolerability limit add 0.01% to overall individual risk for average person

Tolerability Limits – Societal Risk

- UK HSE
  - 50 people at more than 2 x 10^{-4} per year is intolerable
  - Slope of -1 (no aversion)





Legislative Requirements (UK)

- Health & Safety at Work etc. Act 1974 (HASWA)
  - "It shall be the duty of every employer to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his/her employees"

- Management of Health & Safety at Work Regulations 1999
  - "Every employer shall make a suitable and sufficient assessment of-

    (a) the risks to the health and safety of his employees to which they are exposed whilst they are at work; and

    (b) the risks to the health and safety of persons not in his employment arising out of or in connection with the conduct by him of his undertaking"

- Pipelines Safety Regulations (PSR) 1996
  - Goal-setting
  - Design, construction and safety systems – reasonably practicable
  - MAPD (MAHPs only)
    - All hazards identified and risks arising from those hazards evaluated

Code Requirements

- IGEM/TD/1 Edition 5
  - Affirmation of MOP including infrastructure survey – every 4 years
    - 'TD/1 Survey'
  - QRA allowed to justify proximity & population density infringements as part of a safety evaluation
  - Cost benefit analysis to demonstrate ALARP required when
    - Individual Risk is in the tolerable region, or
    - Societal Risk is outside the broadly acceptable region
- PD 8010-1:2015
  - Currently lighter on O&M details but does require Affirmation of MAOP in accordance with IGEM/TD/1
  - HSE does expect operators of pipelines designed to earlier versions of PD 8010 to complete this
- IS 328-2015 broadly similar to IGEM/TD/1
  - Review of MOP every 4 years

Good Practice

- 1st step in an ALARP assessment is to determine if relevant good practice risk reduction measures have been adopted
  - Defined by recognised codes / standards / ACOPs / etc.
- Design, construction, operation and maintenance to IGEM/TD/1 or PD 8010:1 considered to be good practice by HSE
  - Implicit assumption that risk levels of pipelines to code are ALARP
    - QRA of the residual risk used where code is infringed
  - Be careful with cherry-picking!

Cost Benefit Analysis Process

- Similar in both UK and ROI
  - Calculate the Cost of Preventing a Fatality (CPF) or Implied Cost of Averting a Fatality (ICAF)
    - Sometimes called Cost per Life Saved or Cost per Casualty Averted
  - Compare with Value of Preventing a Fatality (VPF) or Defined ICAF criterion
    - UK - Approximately £1 million in 2001
    - ROI - €2.5 million in 2015
  - Determine the Disproportion Factor (DF) or Gross Disproportion Factor (GDF)
    - Robust justification needed if less than 10
      - i.e. CPF or ICAF should be greater than £20 million / €25 million
    - In practice QRAs use a larger value to account for uncertainty in frequency and consequence predictions

Cost of Preventing a Fatality

$$CPF = ICAF = \frac{Cost\ of\ Risk\ Reduction\ Measure}{Reduction\ in\ Potential\ Loss\ of\ Life}$$

$$= \frac{Annualised\ Cost}{\Delta EV} = \frac{Cost}{\Delta EV \times Remaining\ Life}$$

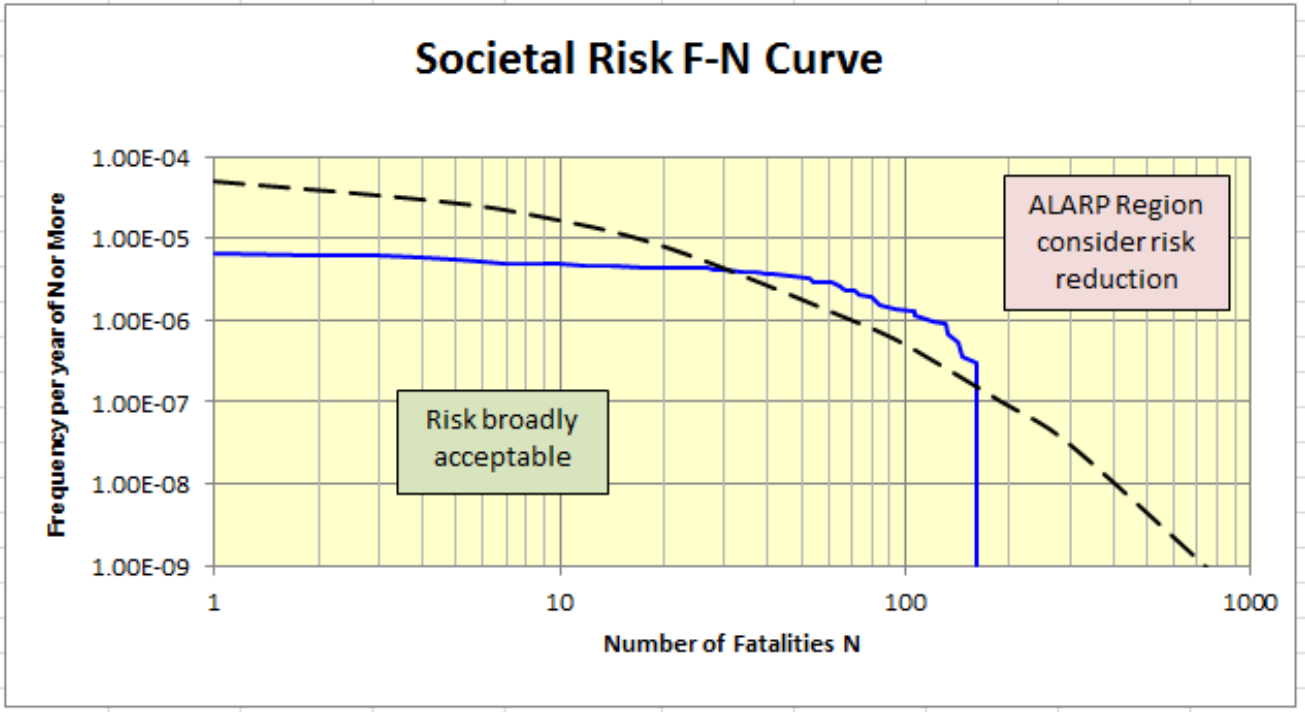
- EV = Expectation Value (statistical expression for average number of casualties per year)
  - Potential Loss of Life (PLL)

$$EV = \sum f.n$$

- Equivalent to area under FN curve

CBA Example

- S-area infringement assessed by QRA
  - Risk in Tolerable if ALARP region
    - Consider additional risk reduction
    - Assess using CBA



Example – Possible Risk Reduction

- Daily Surveillance
  - Additional vehicle use and technician time = £1,750 per year
- Concrete Slabbing for length of infringement
  - 100 m of slabbing @ £1000 / meter = £100,000 or £2,500 per year
- Relay in thick-wall for length of infringement
  - 100 m including hot tap and stopple = £720,000 or £18,000 per year
- Typical to assume remaining life is always 40 years for gas networks

Example – CBA Results

Risk Reduction Measure	Original Expectation Value	Reduced Expectation Value	Annualised Cost	VPF / ICAF	GDF
Surveillance	3.62×10^{-5}	1.42×10^{-5}	£1,750	£79.5 million	39.8
Slabbing		8.10×10^{-6}	£2,500	£89.0 million	44.5
Relaying		7.80×10^{-6}	£18,000	£633.8 million	316.9

- All options are grossly disproportionate and existing risk levels are ALARP
  - Could anything else be considered?

Considerations

- Risk reduction models and factors exist for
  - Thicker-wall / Deeper cover / Increased surveillance / Concrete slabs
  - But what is the effect of increased land-owner liaison or improved marker posts?
- Managerial or procedural risk reduction measures need to be maintained for life of pipeline
  - Given changes in industry over last 40 years HSE may struggle to believe this!
- Would a shorter length of slabbing or thick-wall be better?
  - May depend on the location of the majority of the effected population
  - Sensitivity study if GDF is close to 10?

Questions?