ALARP Risk-informed Decision Framework Applied to Public Utility Safety

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What is ALARP?

- ALARP stands for As Low As Reasonably Practicable
- For each identified threat, ALARP is a risk-informed decision framework used to help answer two questions:
  1. Is risk mitigation needed?
  2. If it is needed, how much must to be spent before the mitigation may stop? Answer to 2. is based on a cost/benefit ratio test. Risk mitigation must continue until cost **grossly and disproportionally** exceeds benefit.

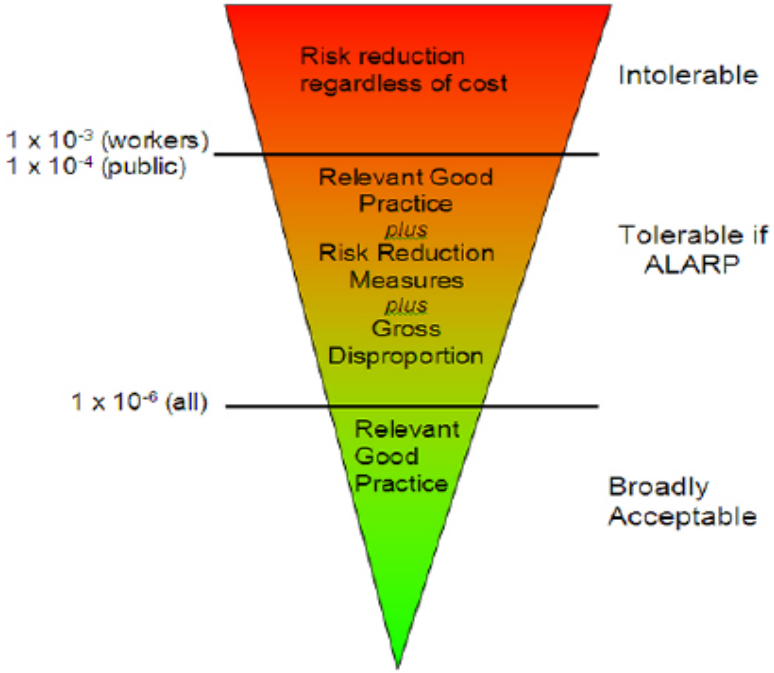
What is ALARP?

- Concept started in the UK based on appellate court decision (Edwards v. National Coal Board, 1949). Formally adopted into UK law by the Health and Safety at Work etc. Act 1974 (HSWA). Regulation administered by the Health and Safety Executive (HSE).
- U.S. has similar concept: ALARA, As Low As Reasonably Achievable used in the nuclear industry.
- ALARP is practiced by US Army Corps of Engineers.

How does ALARP work?

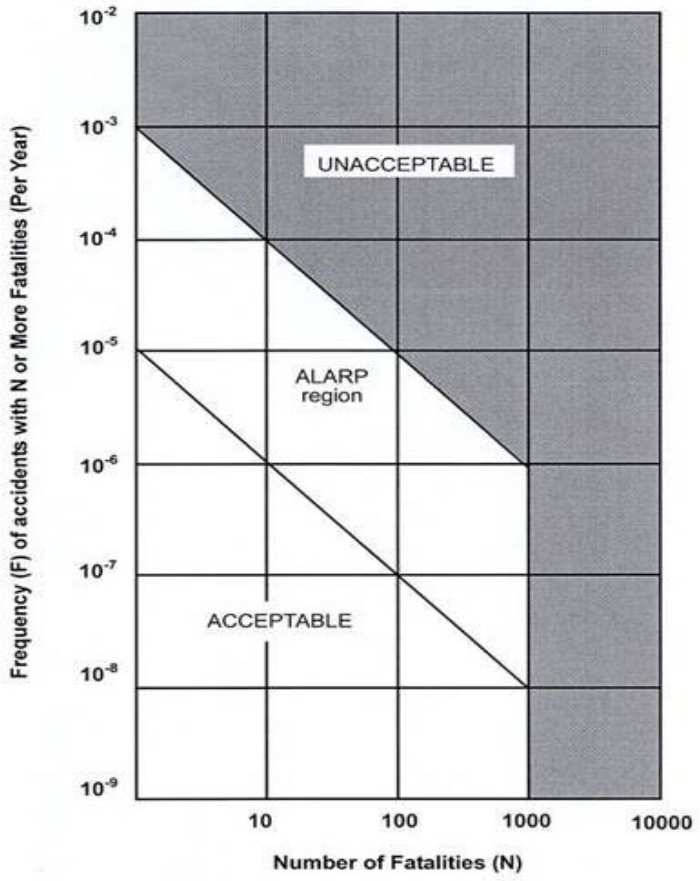
(Symbolic Explanation)

- ALARP is traditionally explained by symbolic "carrot diagram." Risk-causing activities fall in one of three regions. Extent of risk mitigation depends on which region the activity falls into.



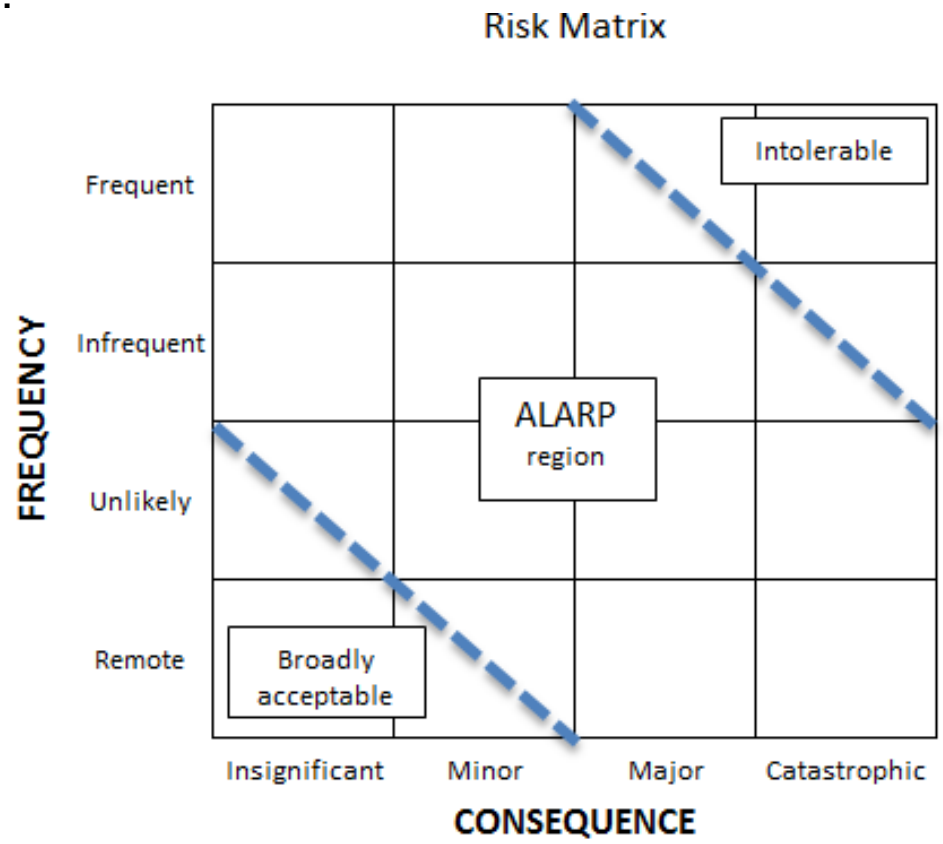
How does ALARP work?

(Realistic ALARP diagram)



How does ALARP work?

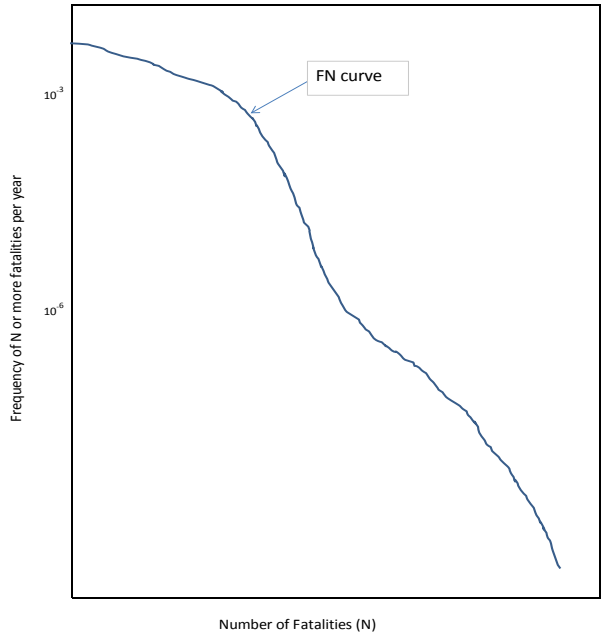
- ALARP diagram can also be explained in terms of risk matrix (risk scores not shown).



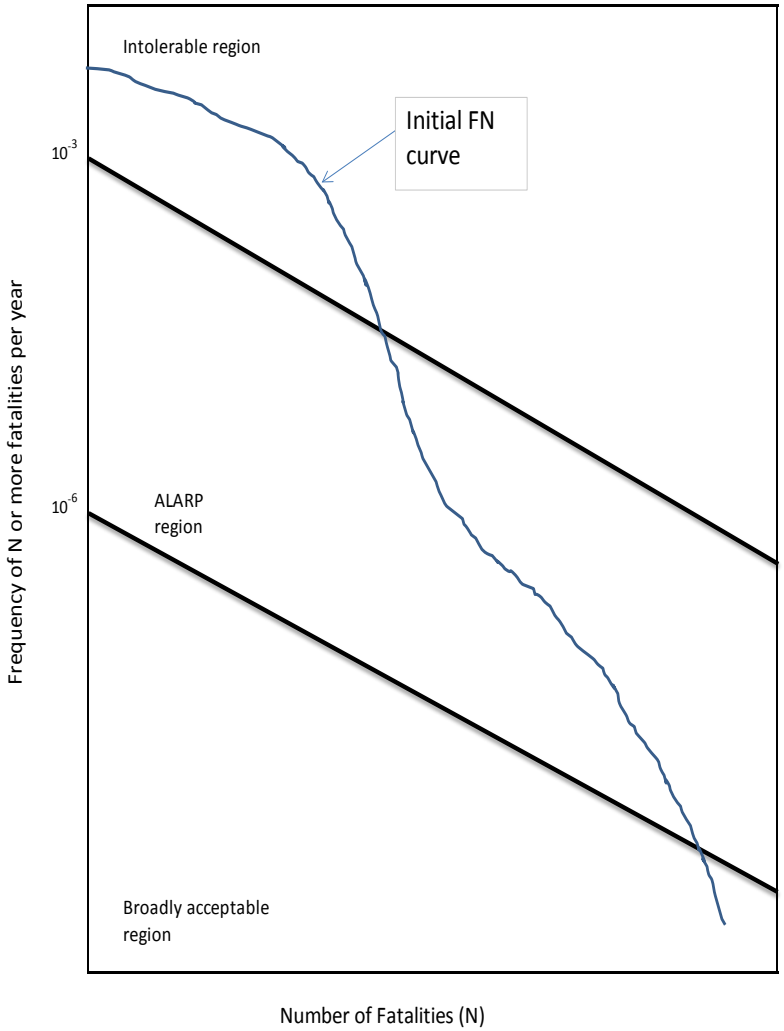
FN Curves

(frequency-fatalities cumulative distribution curves)

- FN curve plots the (expected) frequency (measured in deaths/year) of accidents with **N <u>or more</u>** fatalities per year caused by that threat on the vertical axis against different values of N on the horizontal axis.
- FN curve describes the accident causing potential (measured in frequency of N or more fatalities) of an identified threat, as that threat applies to a utility operator based on the operator's unique circumstances.

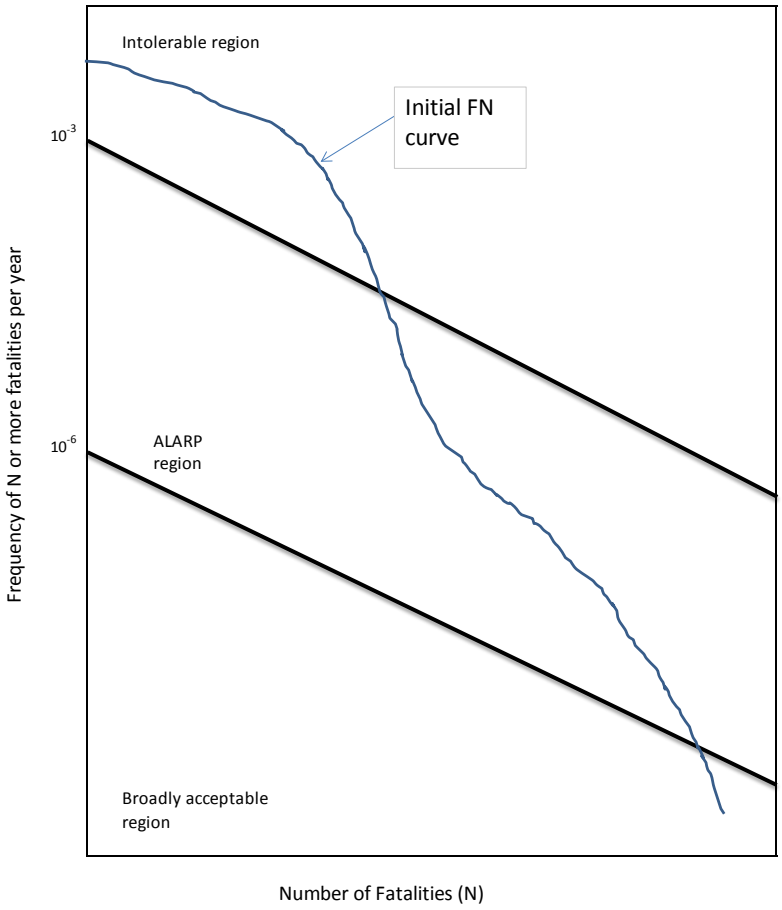


FN Curve overlaid onto ALARP diagram



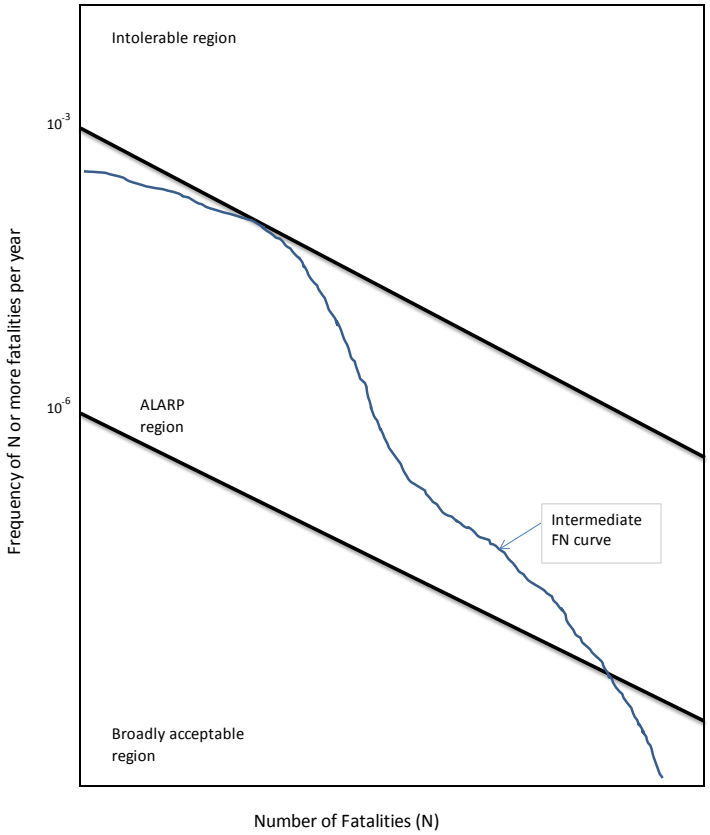
Case 1: FN curve starts in intolerable region

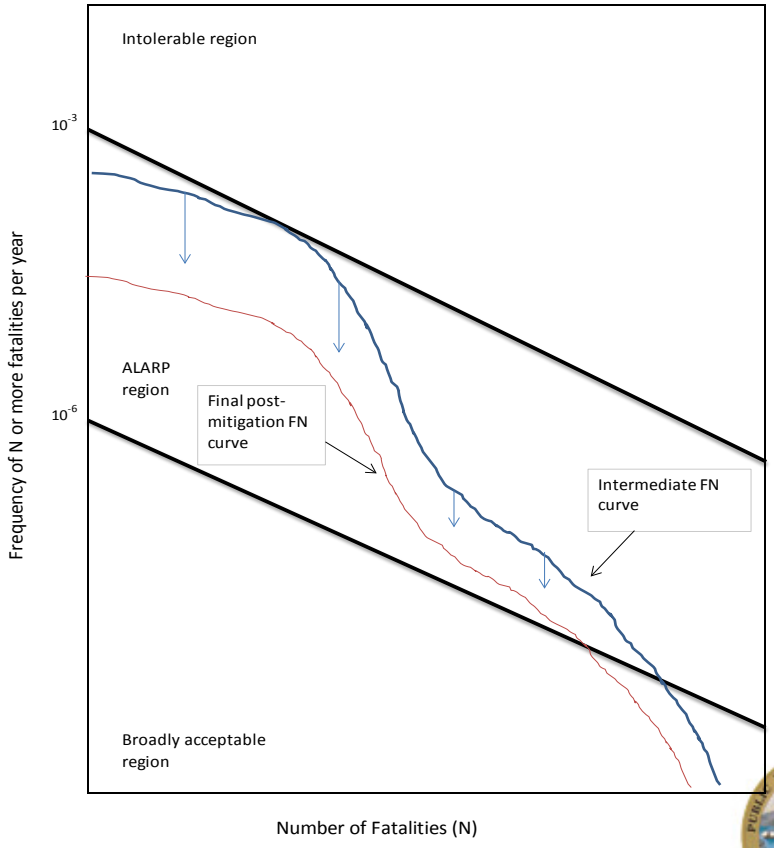
- Must first drive FN curve down to below upper tolerance line.



Case 1 (continued): FN curve starts in intolerable region

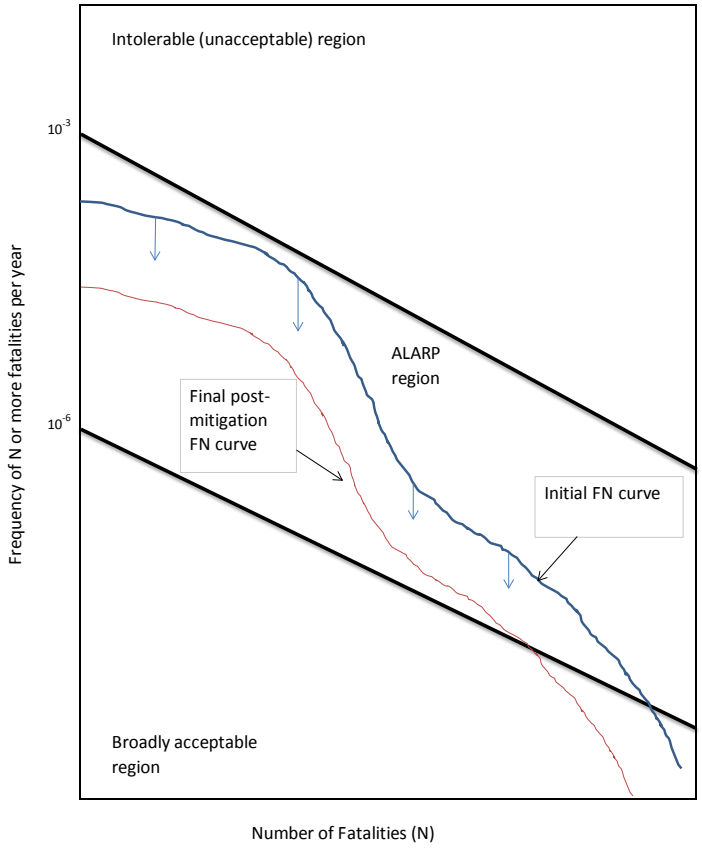
- Must first drive FN curve down to below upper tolerance line.
- Then continue to drive FN curve down until either ALARP criterion is satisfied or FN curve falls below lower tolerance line, whichever comes first.

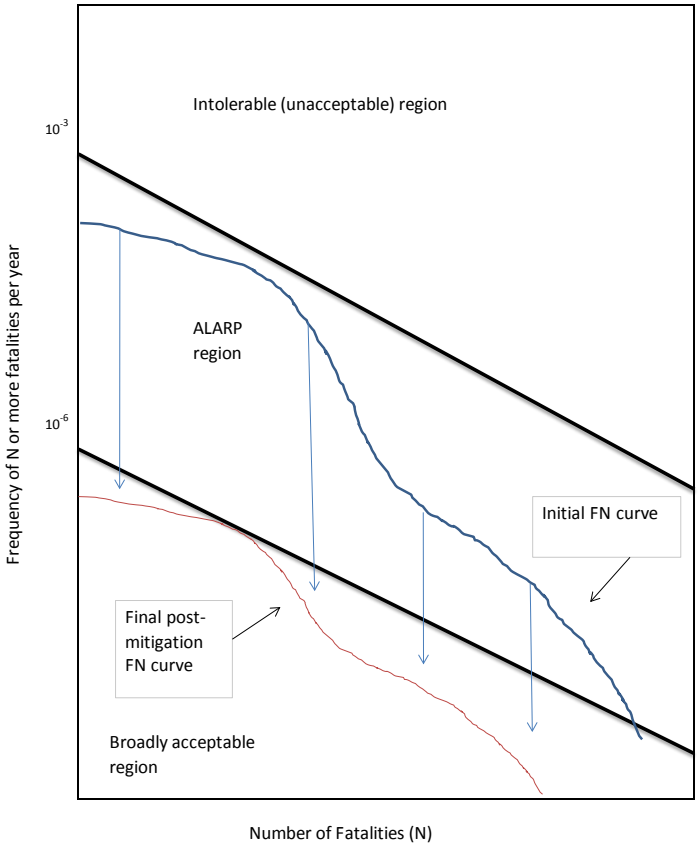




Case 2: FN curve starts in ALARP region

- Drive FN curve down until either ALARP criterion is satisfied or FN curve falls below lower tolerance line, whichever comes first.





Case 3: FN curve starts in broadly acceptable region

- No (additional) risk mitigation is needed, except that necessary to comply with regulations.

ALARP C/B Criterion of Gross Disproportionality

- ALARP criterion: Risk mitigation must continue until cost **grossly and disproportionally** exceeds benefit.
- Demonstration of gross disproportionality can be satisfied by a cost/benefit test:
  - If cost/benefit > gross disproportionality ratio, then risk mitigation may stop.
  - Gross disproportionality ratio should be specified by regulatory entity adopting the ALARP framework, but regulatory bodies have been silent on this ratio. Some give a range of 2 to 10.
- Variation of concept: In the UK, compliance with industry best practices is deemed to be equivalent to satisfying ALARP criterion.

C/B test complications

- Costs and benefits measured either incrementally or cumulatively. Each approach has advantages and drawbacks.
  - Incremental approach (e.g. yearly) can produce wildly varying C/B ratios from period to period, leading to stop and go decisions.
  - Cumulative approach much more susceptible to front-loading of costs.
  - Best approach may be some combination of incremental and cumulative approach, i.e. incremental approach with long periods.

How does ALARP differ from traditional CBA?

- Traditional CBA: go vs. no-go decision based on whether benefit is greater than cost, i.e. as long as C/B<1 continue mitigation. If C/B >1, stop mitigation.
- ALARP first looks at the regions in which the FN curve lies to decide whether risk mitigation is even necessary.
- ALARP then applies C/B test of gross disproportionality: if C/B>gross disproportionality ratio, then stop mitigation.

Value of Statistical Life (VSL)

- Value of life is for a statistical life and not for an identified or unique individual life.
- C/B test requires monetization of injuries and human lives because costs are expressed in monetary terms.
- C/B analysis (CBA) using monetized human lives is already widely practiced in federal government.
- Executive Orders 12866 and 13563 require federal agencies to conduct CBA when evaluating proposed regulations. The orders in effect require agencies to use monetized value of statistical lives to conduct CBA.

VSL estimates

- There are many approaches to VSL estimates. We pick USDOT estimate only as illustration. The 2014 revision of the DOT Guidance identifies $9.2 million as the best point estimate of VSL for base year 2013, with a low end estimate of $5.2 million and a high end estimate of $13.0 million.
- For future years:

  $VSL_{2013+N} = VSL_{2013} \times 1.0118^{N}$

  where VSL_{2013+N} is the VSL value N years after 2013

VSL estimates

The DOT Guidance also lists a table to show the relative equivalent fraction of VSL for various levels of injury:

AIS Level	Severity	Fraction of VSL
AIS 1	Minor	0.003
AIS 2	Moderate	0.047
AIS 3	Serious	0.105
AIS 4	Severe	0.266
AIS 5	Critical	0.593
AIS 6	Unsurvivable	1.000

VSL estimates

- Care should be taken to choose an appropriate VSL. VSL value selected affects ALARP C/B test result.
- But selection of precise VSL is less critical under ALARP than in traditional CBA.
- Error in VSL would be moderated by selection of gross disproportionality ratio since VSL and gross disproportionality ratio work in tandem in affecting ALARP C/B test result.

ALARP risk tolerance limits vs. ERM risk tolerance

- ALARP risk tolerance limits have upper and lower values and are based on safety-related risk.
- ERM safety-related risk tolerance is a single value.
- In the long run, ERM safety-related risk tolerance must fall between the ALARP risk tolerance limits.

ALARP vs. Optimization of portfolio of risk mitigations

- ALARP does not select optimum. ALARP only tells an operator whether enough has been spent on risk mitigation. ALARP does not specify what precise mitigations to use or how quickly to apply risk mitigations.
- Optimization is needed in conjunction with ALARP to select portfolio of mitigations to: 1) minimize total cost at fixed level of total risk reduction, 2) maximize total risk reduction at fixed portfolio cost, or 3) to produce some other optimal outcomes subject to constraints.

Best Practices under ALARP

- Deviation from UK's ALARP approach: This paper does not equate adoption of best practices with satisfying the ALARP criterion. Primary reason is ALARP may possibly produce results more stringent than best practices.
- Example1: ALARP with optimization results in less risk mitigation than best practices. Follow ALARP unless regulations dictate following best practices.
- Example 2: ALARP with optimization results in more risk mitigation than best practices. Follow ALARP result.

Hurdles to Acceptance of ALARP

- Need to place value on statistical life.
- Unfamiliarity with ALARP concept and probabilistic approach in general.
- Lack of data and deficiencies in models.
- ALARP requires explicit risk tolerance limits.
- For mitigation activities that may yield overlapping benefits, there is no clear way to attribute any benefit tied to any threat to any particular risk mitigation activity.
- Regulators, operators, intervenors, and public need to accept tradeoff between safety and rate affordability.

Conclusion: Why adopt ALARP?

- ALARP approach works hand in hand with probabilistic risk management approach. ALARP can help drive probabilistic approach.
- ALARP approach with portfolio optimization yields lowest cost, maximum safety, or some optimal combination of the two.
- ALARP can demonstrate in objective way the tradeoff between safety and rate affordability. ALARP gives definite regulatory signal of what is an acceptable tradeoff.
- Adoption of ALARP helps overcome operators' reluctance to state explicit risk tolerance. Explicit risk tolerance is needed to perform optimization with precision.

Thank You

For Additional Information:

www.cpuc.ca.gov/PUC/safety/Risk_Assessment.htm