Risk Assessment
4. Risk acceptance criteria

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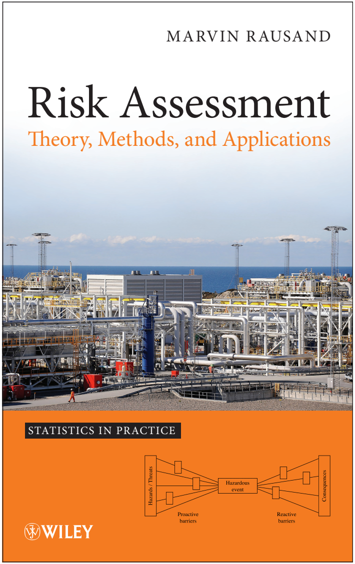
Slides related to the book

Risk Assessment
Theory, Methods, and Applications

Wiley, 2011



Homepage of the book:
http://www.ntnu.edu/ross/books/risk

Balancing risks and benefits

- Need to identify what the risks are, introduce risk reducing measures and thereby improve the situation
- In the end, two conflicting objectives need to be balanced:
  - We have a desire to do everything physically possible to remove all risks
  - The reality is that we have limited resources and that it is nearly always not practical (nor physically possible) to remove all risk
- The question is then:
  - How much risk do we remove before we stop? How do we balance the two objectives?
- The level where we stop is defined by an acceptance criterion
- The remaining risk or residual risk is the risk that remains after we have introduced relevant measures

Definitions

NS 5814 "Requirements for Risk Assessment"

- NS 5814 requires that "the results of risk analysis must be compared with the criteria for acceptable risk,"
- and that "risk acceptance criteria be established before conducting a risk analysis"

☞ Risk acceptance criteria: Criteria used as a basis for decisions about acceptable risk.

☞ Acceptable risk: Risk that is accepted in a given context based on the current values of society and in the enterprise.

Common qualitative criteria

- All avoidable risks should be avoided.
- Risks should be reduced wherever practicable.
- The effects of events should be contained within the site boundary.
- Further development should not pose any incremental risk.

- No single failures/errors should lead to an accident.

Acceptable and tolerable risk

Tolerability refers to the willingness to live with a risk so as to secure some certain benefits and in the confidence that it will be properly controlled [...]

To tolerate a risk means that we do not regard it as negligible or something we might ignore, but rather as something we need to keep under review and reduce still further if and as we can.

For a risk to be acceptable on the other hand means that for purposes of life or work, we are prepared to take it pretty well as it is.

Approaches to risk reduction

Possible approaches to risk reduction and risk management:

- Utility – Measure risk reduction against cost.
  - Use resources as efficiently as possible for the society as a whole.
- Equality – No member of society should have risk above a given level.
  - Use resources to reduce risk for those who have the highest exposure.
- Technology – Application of "state-of-the-art" technology gives acceptable risk.
  - Based on the assumption that risks already (implicitly) accepted should be acceptable also in the future.

Our view on these issues will necessarily also influence the risk acceptance criteria.

Risk acceptance

Influenced by risk perception

Many factors will influence our view of what we consider to be an acceptable risk. Some key factors are:

- Benefits gained from taking the risk
- Degree of control over the risk – driver vs passenger
- Risk aversion – one catastrophe is worse then many small accidents
  - Perception of risk from industries varies
  - Type of hazard affects risk perception
- Time until effects are experienced
- Time since risk has been "realized" (time since accidents have occurred)

Risk acceptance principles

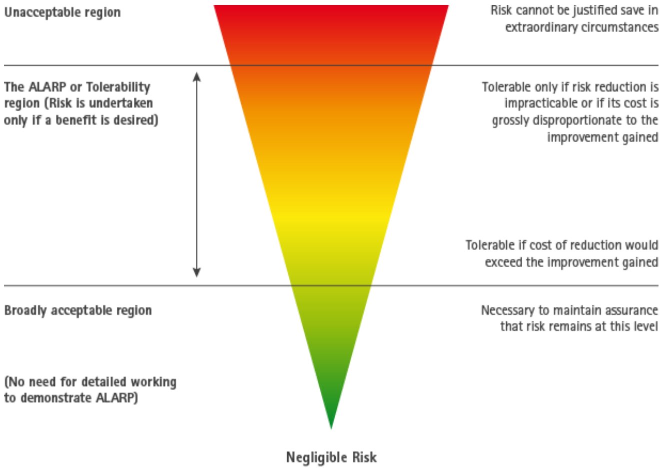
Commonly used principles for risk acceptance are:

- ALARP – As low as reasonably practicable
- ALARA – As low as reasonably achievable
- GAMAB – Globalement au moins aussi bon
- GAME – Globalement au moins équivalent
- MEM – Minimum endogenous mortality
- Societal risk criteria
- Precautionary principle

ALARP

- Principle established by the UK Health and Safety Executive (HSE).
- Introduces the concept of three different “risk zones”
  - Unacceptable region – risk is too high to be acceptable and risk reducing measures must be introduced.
  - ALARP-region – risk is below the unacceptable level, but is not acceptable either without considering further measures to reduce risk.
  - Broadly acceptable region – risk is broadly acceptable and no further measures are considered necessary.
- Tends to act to continuously reduce risk. New measures need to be considered.
- Widely applied principle – is also reflected in the risk matrix.

ALARP


Unacceptable region
Risk cannot be justified save in extraordinary circumstances
The ALARP or Tolerability region (Risk is undertaken only if a benefit is desired)
Tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate to the improvement gained
Tolerable if cost of reduction would exceed the improvement gained
Broadly acceptable region
Necessary to maintain assurance that risk remains at this level
(No need for detailed working to demonstrate ALARP)
Negligible Risk

SFAIRP and ALARA

- SFAIRP = So far as is reasonably practicable.
  - For all practical purposes the same as ALARP

- ALARA = As low as reasonably achievable.
  - Similar to ALARP, but usually refers to a situation where no “lower limit” (negligible risk) is defined.
  - In practice: Risk should always be reduced.

Value of life

- Used in cost-benefit analysis – to compare the cost of a measure with the potential "savings" in fatalities.
- Value of a statistical life (VSL).
  - Not "the price of a life," but an expression of what a company or the public would be willing to pay to reduce risk corresponding to a fatality.
  - Typically relevant only in "low-risk" situations.
- Value of averting (or preventing) a fatality (VAF) and Implied cost of averting a fatality (ICAF) are basically the same
- Societal willingness to pay
  - Life quality index
- Net cost of averting a fatality (ICAF)
  - Cost minus any economic benefits

Value of life
Examples

- Transport industry in Norway
  - The *value of a prevented fatality* (VPF) has been calculated to approximately 25 million NOK.
- Offshore industry
  - NORSOK Z-013 indicates a VPF of 20-100 million NOK
  - VPF may be as high as 500 million NOK in extreme cases.
- Common values are between 1 and 15 million USD

Cost-benefit analysis

Costs - 1

- Consequences must be quantifiable and must be possible to express as a cost.
- Comparison of changes in risk cost versus cost of introducing the risk reducing measures.
- What risk costs should be included?
  - Repair costs
  - Costs related to temporary repairs/solutions
  - Costs related to lost revenue/production
  - Environmental costs including clean-up costs
  - Costs of injuries/fatalities

  ...and so on

Cost-benefit analysis

Costs - 2

- Costs associated with the risk reducing measure:
  - Investment costs
  - Operational costs
  - Risk costs associated with introducing the measure

Cost-benefit analysis
Benefits

$$\text{NPV} = \sum_{n=1}^{N} r_D^{-n} \left[\sum_{j=1}^{3} \Delta C_{nj} \cdot V_j(C) - RC_n - IC_n \right] > 0$$

- NPV – Net present value.
- N – Expected lifetime of the investment, expressed in years.
- r_D^{-n} – Depreciation factor.
- ΔC_{nj} – Change in expected risk in year n for risk type j ($j = 1$: personnel, $j = 2$: environment, $j = 3$: economic values)
- $V_j(C)$ – Valuation of risk type j as a function of risk
- RC_n – Operating cost year n
- IC_n – Investment cost year n

Cost-benefit analysis

Benefits – simplified calculation

- Assume no depreciation factor: $r_D = 1$
- Assume only personnel risk
- Assume investment I only in year 0
- Assume constant operating cost each year
- Assume constant change in risk cost each year

$$\text{NPV} = \sum_{n=1}^{N} [\Delta C_2 \cdot V_2(C) - RC] - IC > 0$$

$$\text{NPV} = N(\Delta C_2 \cdot V_2(C) - RC) - IC > 0$$

Two different views

Company view:

- Limited costs
- Insurance coverage
- Tax effects

  …and so on

⇒ The result is often that no or very few measures are cost-effective.

Societal view:

- Wide consideration of costs and benefits
- Effects of tax, insurance and ownership are eliminated

The societal view is the most commonly used approach

Deterministic costs vs. probabilistic benefits

- Costs are deterministic and known to occur
- Benefits are probabilistic and will most likely never be realized (possibly with the exception of reduced insurance)
  - Expected annual accident cost
  - Purely a statistical cost
- Calculated benefit will never occur:
  - Either you have an accident (with typically very large losses)
  - Or you do not have an accident (with no losses, only investment and operating costs)
- May therefore also be necessary to consider maximum losses, not just "expected" losses

Depreciation of future losses

- Cost-benefit calculations often imply a depreciation of future costs and losses to arrive at a net present value (NPV)
- Basis is financial models
- Is it "correct" to depreciate a future fatality?

Cost-benefit analysis
Railway application

Depreciation is not considered

$$\text{NPV} = \left[\sum_{j=1}^{3} \Delta C_j \cdot V_j(C) - RC - IC \right]$$

A benefit index is calculated as follows:

$$I = \frac{\text{NPV}}{IC + RC}$$

Cost-benefit analysis

Values used

- VSL/VPF values as shown earlier.
- HSE specifies that "multiplication factor" should be used.
  - If risk is close to the upper acceptable limit, a multiplication factor of 10 should be used.

GAMAB

"Globalement au moins aussi bon" (globally at least as good)

- GAMAB is used in France in relation to transport systems:
  - "All new guided transport systems must offer a level of risk globally at least as good as the one offered by any equivalent existing system"
- Requires a continuous improvement in risk for new systems compared to existing systems ("at least")
- Does not consider particular risks – distribution of risks may be different between different systems ("globally")
- A similar principle is applied by the Norwegian railway infrastructure owner (Jernbaneverket) relative to system changes

MEM

Minimum endogenous mortality

- Also applicable to transport systems, applied in Germany.
- This principle has been derived as follows:
  - Deaths due to “technological facts” (includes, e.g., work, machines, transport, do-it-yourself activities, entertainment and sport etc) is called “Endogenous Mortality,” R.
  - In developed countries, this risk is lowest for the age group 5-15 years. This risk level is called the “minimum endogenous mortality,” R_m.
  - The principle is that R_m should not increase significantly as a results of a new transport system.
- R_m has been defined as $2 \cdot 10^{-4}$ fatalities/per person per year.
- Maximum increase has been set at 10^{-5} fatalities/per person per year.

Societal risk criteria

- HSE (UK): "The risk of an accident causing the death of 50 or more people in a single event should be regarded as intolerable if the frequency is estimated to be more than one in five thousand per annum."
- PSA (Norway):[1] "The frequency of impairment of main safety functions should be less than 1 in 10000 per accident type per year"

[1] PSA = Petroleum Safety Authority

Precautionary principle

- The precautionary principle was acknowledged at the UN conference in Rio de Janeiro in 1992:

  Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty shall not be used as a reason for postponing effective measures to prevent degradation

- The overriding principle is that even if there is no scientific evidence that there is a connection between cause and effect, cost-efficient measures to reduce risk should still be introduced

  "Absence of evidence of risk" $\neq$ *"Evidence of absence of risk"*

- Formulated in relation to global environmental effects, but is also being applied more widely.

Application of PP by HSE

The precautionary principle should be invoked where:

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

Summary of principles

- ALARP – maximum tolerable level, try to improve below this level.
- GAMAB – new systems should be at least as good as existing systems.
- MEM – new systems should not increase "technological risk" significantly.
- Precautionary principle – even if we have no confirmation that there are adverse consequences, this should not stop risk reduction measures from being introduced.

Acceptance criteria

Example for personnel risk

- Maximum acceptable FAR value 10
- Maximum acceptable Individual Risk 10^{-3} per year, negligible risk 10^{-5} per year combined with the ALARP principle.
- Maximum acceptable frequency of loss of safety (critical) functions
- No identified hazards are to be classified in the "red zone" in the risk matrix
- When changes to the system are introduced, the risk level after the change should be at least as good as before the change.

Environmental criteria

- The assessment of the ultimate effects from product releases into the environment is difficult, especially in the case of a typical accidental release.
- There may be no immediate loss of plants or animals or other observable effects from single releases, but there may be cumulative and synergistic effects.
- In many cases, it may not be possible or practicable to establish the final impact of any particular release.
- It may be appropriate in such circumstances to assess the likelihood of identified concentrations of concern in the air, water or soil.
- The risk levels for accidental releases to the environment can be summarized in terms of probability and consequence.

Economical/financial risk

- Acceptance criterion will typically be a simple cost-benefit calculation.
- As long as the risk reduction achieved from introducing new risk reducing measures is greater then the cost involved in introducing the measure, measures are introduced.
- Usually an area the authorities are not concerned with – exception may be if an industry or activity is of great national importance.

Requirements to risk metrics

- Need to be a good measure of the parameter we are interested in measuring:
  - Risk to human life, to the environment, or economical risk?
  - Does the measure give the answer to how the risk level changes?
- Must be possible to observe and quantify with reasonable certainty to enable us to record data and thereby observe changes and trends.
- Must be sensitive to changes in risk, to allow us to detect changes early and thereby take actions.
- Must be easy to understand and use for decision makers and other users.
- Must be robust against manipulation.

Factors to consider when setting acceptance criteria

- Criterion must be possible to meet!
- Should be able to reflect changes in activity level.
- How are we going to measure risk? Is it possible to measure the risk?
- Is the risk level commonly accepted in the society, or not?
- Can the acceptance criterion be communicated internally and externally in a good way?

More factors to consider

- The criteria should give requirements both to average risk level and high risk activities (usually of short duration)
- Can the risk be compared with the benefit from the activity?
- Risk matrix:
  - Are the categories reasonable?
  - What are the "zones" in the matrix?
- On-site versus off-site risk – first, second, and third party