Risk acceptability and tolerability

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How safe is safe enough?
Warmup. Before reading this material, we suggest you look through:

▷ slides on risk metrics (how to measure risk levels?)
▷ slides on risk perception

Available from risk-engineering.org & slideshare.net
What is risk acceptance?

- Risk acceptance issues affecting **individual decisions**:
  - Should I buy airplane tickets on Tinkertown Airlines, which are 300€ cheaper than Air Reliable?
  - Do I go skiing hors piste?

- Risk acceptance issues affecting **societal decisions**:
  - Encourage nuclear power plants, or coal-fired plants, or increased electricity pricing?
  - Should we allow genetically modified foods?

- Note: risk acceptance is often controversial both in theory and in practice...
Where does this fit into risk engineering?

- Data
- Probabilistic model
- Event probabilities
- Consequence model
- Event consequences
- Risks

Curve fitting
Where does this fit into risk engineering?

- Data
  - Curve fitting
  - Probabilistic model
  - Event probabilities
  - Risks
  - Decision-making

- Consequence model
  - Event consequences
  - Costs
  - Criteria
Where does this fit into risk engineering?

data → probabilistic model → event probabilities → risks

data → consequence model → event consequences → risks

curve fitting

costs

decision-making

criteria

These slides
Risk acceptance criterion

- **Criterion**: a standard of judging; any established law, rule, principle or fact by which a correct judgment may be formed

- **Risk acceptance criteria**: criteria used as basis for decisions about acceptable risk, during the **risk evaluation** phase of risk analysis

- **Risk evaluation**: comparison of risk analysis results with risk criteria in order to determine whether or not a specified level of risk is acceptable or tolerable
Some examples of qualitative risk acceptance criteria:

- “All avoidable risks shall be avoided”
- “Risks shall be reduced wherever practicable”
- “The effects of events shall be contained within the site boundary”
- “Further development shall not pose any incremental risk”
Risk acceptance criterion

- Risk acceptability is inherently contingent on time and situations, and is hence never absolute, nor universal:

  "The act of adopting an option does not in and of itself mean that its attendant risk is acceptable in any absolute sense. Strictly speaking, one does not accept risks. One accepts options that entail some level of risk among their consequences."

- An extensive social sciences literature develops these concepts and relationships with risk perception, trust, communication and governance.

Source: Acceptable Risk, Fischhoff et al. 1981
“Tolerable” risk

- UK Health and Safety Executive distinguishes between tolerable and acceptable risks:

  “Tolera/blility” does not mean “acce/ptability”. It refers to a willingness to live with a risk so as to secure certain benefits and in the confidence that it is being properly controlled. [...] 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.

- ISO 31000 standard:
  - risk appetite: the amount and type of risk that an organization is prepared to pursue, retain or take
  - risk tolerance: organization/stakeholder’s readiness to bear risk after risk treatment in order to achieve its objectives

Source: The tolerability of risk from nuclear power stations, UK HSE, 1992
Factors influencing risk acceptance

- Objective level of risk generated by a project
- Is the origin of the risk natural or industrial/technological?
- Is the nature of the hazard familiar or unfamiliar?
- Are the possible effects memorable or easily forgotten, dreaded or not?
- Is the hazard of a catastrophic or a chronic nature?
- Is exposure to the risk perceived to be fair or unfair?
- Is the activity perceived to be morally relevant?
- Are sources of information concerning the risk and the activity perceived to be trustworthy?
- Is the governance of the industrial activity and the risk management process perceived to be open and responsive?
Decision rules
Absolute risk targets

▷ **Aviation** safety: probability of catastrophic failure should be less than $10^{-9}$ per flight hour
  
  • other targets for Hazardous, Major and Minor severity effects
  
  • accompanied by a design principle: *In any system or subsystem, the failure of any single element, component, or connection during any one flight should [...] regardless of its probability [...] not be Catastrophic.*

▷ **Air traffic management:**
  
  • maximum tolerable probability of ATM directly contributing to an accident of a commercial air transport aircraft of $1.55 \cdot 10^{-8}$ accidents per flight hour

▷ **Maritime** safety, for new ships:
  
  • maximum tolerable probability of fatality for crew members: $10^{-4}$ per ship-year
  
  • maximum tolerable probability of fatality for passengers or public: $10^{-5}$ per ship-year
▷ Risk matrices are widely used in the process industry

▷ Companies and regulators use specific frequency and consequence thresholds
  • where is the cutoff between “infrequent” and “fairly frequent” for our activity?
The risk matrix (also called a “heat map”) can be used for three main purposes:
- determine how significant each risk is
- prioritize or rank risks relative to one another to help allocate safety spending
- highlight areas for further more detailed risk assessment (e.g. fully quantitative rather than qualitative for higher level risks)

When used for decisions related to acceptability of a hazardous activity, the aggregate risk level should be used
- all risks from the facility added together then positioned in the matrix
- it’s not sufficient for each accident scenario from the facility to be in an “acceptable” location of the matrix, considered in isolation!
ALARP principle

**risk**

- **Unacceptable region**
  - Risk can only be justified under extraordinary circumstances

- **Tolerable region**
  - Risk must be reduced ALARP

- **Broadly acceptable region**
  - Risk is negligible and/or adequately controlled

**ALARP: As Low As Reasonably Practicable**
The ALARP principle is fairly widely used
- used for example by UK HSE

Much discussion revolves around interpretation of the term “reasonably”
- companion principle ASSIB (“And Still Stay In Business”) is also important

To determine “reasonably practicable”, either:
- refer to industry standards and good practice
- use benefit-cost analysis with a “gross disproportion factor”
MEM decision rule

▷ MEM: Minimum Endogenous Mortality

▷ Basis:
  • there are different mortality rates in society, depending on age and gender
  • these deaths are partly caused by hazardous industrial systems

▷ Decision rule: new system should not lead to a significant increase in risk estimated for a population with the lowest endogenous mortality
  • number of natural deaths is the reference point for acceptability

▷ Mostly used in Germany, for railways

Endogenous mortality: deaths due to internal causes (disease, aging)
GAME decision rule

- **GAME**: *Globalement au Moins Equivalent*, or Globally at least equivalent
- Mainly used in French railways
- The EN 50126 standard:
  - “All new guided transport systems must offer a level of risk globally at least as good as the one offered by any equivalent system”
- Example: Channel Tunnel Safety Authority imposed a requirement that the safety performance of the Tunnel should be no worse than that of a surface railway of similar length
- Note: requires an existing system which acts as the reference
“Best available technology” rule

▷ BAT: Best available technology
  • a regulatory principle which is widely used to control environmental risks
  • emissions limit values and the equivalent parameters and technical measures in permits shall be based on the best available techniques, without prescribing the use of any technique or specific technology
  • “available” means developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages

▷ BATNEEC (Best available techniques not entailing excessive costs):
  applied to air pollution emissions from large industrial installations (EU directive 84/360/EEC)
## Criteria used by US federal regulatory agencies

<table>
<thead>
<tr>
<th></th>
<th>Individual risk considered</th>
<th>Population risk considered</th>
<th>Usual acceptable residual risk (lifetime risk for lifetime exposure)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Toxics</strong></td>
<td>Yes</td>
<td>Yes, indirectly</td>
<td>Unstated, but usually $10^{-6}$ to $10^{-5}$ for public, $10^{-4}$ to $10^{-5}$ for occupational exp.</td>
</tr>
<tr>
<td><strong>Pesticides</strong></td>
<td>No for carcinogenic additives; yes for residue tolerance</td>
<td>Yes for residue tolerance</td>
<td>Zero for additives (Delaney clause) $10^{-5}$ for assumed max residues in average diet, $10^{-6}$ for non-dietary exposure</td>
</tr>
<tr>
<td><strong>drinking water</strong></td>
<td>Yes, a standard exposure scenario in middle range</td>
<td>No</td>
<td>$10^{-3}$ to $10^{-4}$ range considered to be adequate</td>
</tr>
<tr>
<td><strong>water quality</strong></td>
<td>Yes, a standard exposure scenario in middle range</td>
<td>No</td>
<td>$10^{-6}$ to $10^{-7}$</td>
</tr>
<tr>
<td><strong>hazardous waste handling, active disposal</strong></td>
<td>Yes</td>
<td>No</td>
<td>listing: $10^{-5}$ corrective actions: $10^{-4}$ to $10^{-6}$ incinerators: $10^{-5}$</td>
</tr>
<tr>
<td><strong>Superfund sites</strong></td>
<td>Yes, &quot;reasonable maximum exposure &quot; using mix of midrange and conservative assumptions</td>
<td>Yes</td>
<td>$10^{-4}$ to $10^{-5}$, depending partly on anticipated future use of site</td>
</tr>
<tr>
<td><strong>hazardous air pollutants</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>$10^{-4}$ to $10^{-6}$</td>
</tr>
<tr>
<td><strong>food additives, colours and contaminants; cosmetics</strong></td>
<td>No for carcinogenic additives; yes for additives, contaminants</td>
<td>No</td>
<td>Zero for additives; $10^{-6}$ for assumed max residues in &quot;high use&quot; diet</td>
</tr>
<tr>
<td><strong>occupational exposure</strong></td>
<td>Yes, for full working life at possible exposure limit</td>
<td>No</td>
<td>Feasible controls (in practice $10^{-3}$)</td>
</tr>
</tbody>
</table>

**Note absence of homogeneity for different risk categories...**

The precautionary principle

- The purpose of the precautionary principle is to create an impetus to take a decision notwithstanding scientific uncertainty about the nature and extent of the risk

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

— 1992 Rio Declaration on Environment and Development

- Simpler definition: incomplete scientific knowledge is not a valid excuse for regulatory inertia
The precautionary principle

▷ UK guidance: precautionary principle should be invoked when:
  • there is good reason, based on empirical evidence or plausible causal hypothesis, to believe that harmful effects might occur, even if the likelihood of harm is remote
  • a scientific evaluation of the consequences and likelihoods reveals such uncertainty that it is impossible to assess the risk with sufficient confidence to inform decision-making

Source: hse.gov.uk/aboutus/meetings/committees/ilgra/pppa.htm
The Imperative of Responsibility [Jonas]

▷ Hans Jonas (1903–1993), German philosopher

... the frivolous joyous human holiday of several industrial centuries will perhaps be paid for by thousands of years of transformed terrestrial life.

▷ The Imperative of Responsibility: in Search of an Ethics for the Technological Age (1979)
• human survival depends on our efforts to care for our planet and its future
• we have a responsibility to future generations
• Jonas’ supreme principle of morality: “Act so that the effects of your action are compatible with the permanence of genuine human life”
• inspired the environmental movement in Germany in the 1970s
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