SPECIAL MOBILITY STRAND

Framework for risk assessment using scenarios
Henrik Hassel
University of Tirana, 2019-01-21

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Who am I and where do I come from?

- Associate professor
- Program director – Master program in Risk Management and Safety Engineering
- Research concerning risk and vulnerability assessment for critical societal functions
- Teaching risk assessment – mainly industrial safety context

- Lund University/Division of risk management and safety engineering
  - 3 educational programs within risk and disaster management
    Broad set of research activities – Swedish and international context

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Content

- What is risk and risk assessment?
- Why perform risk assessments?
- Challenges for risk assessments
- A framework for risk assessment

- Mainly exemplified in an industrial safety setting – but most principles apply for other contexts and applications

What experiences do you have related to risk assessments?

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What is risk?

Uncertainty about what will happen in the future is in the centre of all definitions

- How do you define ”risk”?
- Some common definitions:
  - Risk is the combination of probability and severity of adverse effects
  - Risk is uncertainty and severity of negative consequences
  - Risk is the possibility that human actions or events lead to consequences that affect what humans value
  - Risk equals expected loss
  - Risk is the combination of hazard and vulnerability
- Differences?

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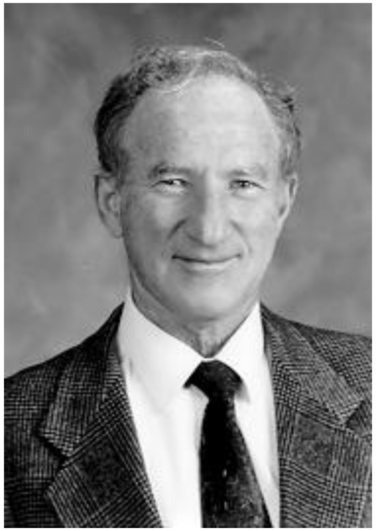
It is not straightforward to define risk….

"The words of risk analysis have been, and continue to be a problem. Many of you here remember that when our Society for Risk Analysis was brand new, one of the first things it did was to establish a committee to define the word 'risk'. This committee laboured for 4 years and then gave up, saying in its final report, that maybe it's better not to define risk. Let each author define it in his own way, only please each should explain clearly what way that is."



Stanley Kaplan

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A pragmatic definition of risk

- Risk is the answer to the questions:
  - What can happen?
  - How likely is it?
  - What will the consequences be?
- Scenario-based definition!

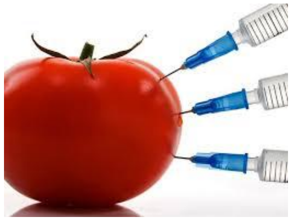
- References:

  - Kaplan, S. and Garrick, B. J. (1981). "On The Quantitative Definition of Risk", Risk Analysis 1(1): 11-27
  - Kaplan, S. (1997). "The Words of Risk Analysis" Risk Analysis 17(4): 407-417.
  - Kaplan, S., Haimes, Y. Y. and Garrick, B. J. (2001). "Fitting hierarchical holographic modeling into the theory of scenario structuring and a resulting refinement to the quantitative definition of risk" Risk Analysis 21(5): 807-819.

Need for risk assessments (and risk assessors)

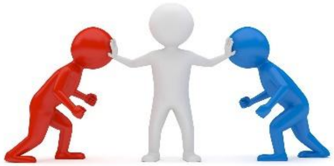
- Input to decisions concerning risk, e.g. show acceptable risk in industries, projects, etc.
- Identify critical elements that risk reductions should focus on
  - Scenarios, components, geographical areas, activities etc.
- A *process* that in itself is fruitful
- Growing need due to:
  - Technology development, global changes, increased public demands…
- People with knowledge about the principles and methods of *risk analysis* is crucial!

Challenges for risk assessment



- Uncertainty
  - Lack of knowledge and information – e.g. GMO crops

- Complexity
  - Cause-effect relationships unknown, non-linear relationships – e.g. atmospheric system
- Ambiguity
  - Different stakeholders draw different conclusions from the same ”facts” – e.g. nuclear power/weapons



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References:
Aven and Renn (2010). Risk management and governance – concepts, guidelines and applications

A framework for risk assessment

Risk assessment (Risk evaluation through Values/Objectives)

Risk analysis (Likelihoods och consequences through Values/Objectives)

Risk evaluation	Should the risk be accepted? Which alternative should be chosen?
Risk presentation	How high/low is the risk in the system?
Likelihoods och consequences	What are the likelihood and consequences of the risk scenarios?
Risk scenarios	What can happen (go wrong)?
Context and System description (Functional / Structural models)	How do we percieve the world? What is ”normal”?
Values/Objectives	What is important to protect?

Values and objectives

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Values and objectives

- What is worth protecting (or achieving)?
- Heavy rainfall – risk or not?
  - A *risk* for the tourist that wants to lie on the beach
  - An *opportunity* for the umbrella salesman
  - A *risk* for the family with a flood-prone basement
  - An *opportunity* for the farmer in need of water for the fields
- Depends on perspective/preferences – subjective choice!
- The value basis has a major influence on the outline of the
  isk analysis

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Values and objectives

- What is valuable and important to protect in a building when considering fire hazards?
  - Life and health of occupants,
  - Property, The environment,
  - Production output, Image, Market share…
- What is valuable and important to protect in the community of Tirana?
  - Life and health of citizens,
  - Functionality of critical societal functions,
  - Environmental conditions, cultural values…

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Context and system description

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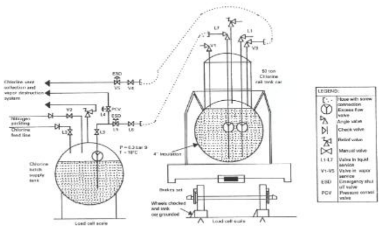
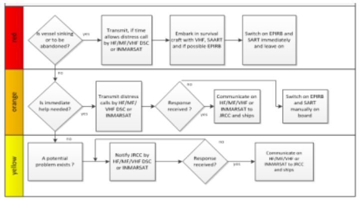
Context and system description

- Risk assessment can focus on many different types of systems/scales:
  - A critical component in an industry, e.g. a pump
  - A unit of or a complete hazardous facility
  - A project with specific project goals
  - An organization performing critical activities
  - A geographical area with all its critical infrastructures
  - An investment, etc.…
- The system, its delimitations, etc. must be described – baseline for the assessment and for being able to communicate results

Context and system description

- System descriptions may focus on many different perspectives – technical, organisational, human, social, etc.
  - Many competencies are needed
  - Involves choices that often must be negotiated
- Many ways to describe a system exist
  - Structural descriptions
  - Functional descriptions
- What you include depends on Relevance, Purpose, Resources





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Risk scenarios

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Risk scenarios

- A scenario is something that happens in a system – a sequence of events
  - Risk assessments aim to describe *risk scenarios* – those that lead to negative consequences for something of value
- The S_0-scenario – As planned/success scenario
  - A description when everything evolves according to "the plan"
  - Good starting point for identifying risk scenarios

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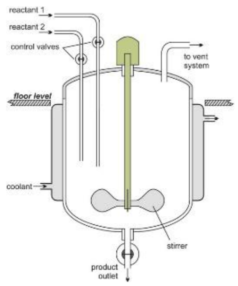
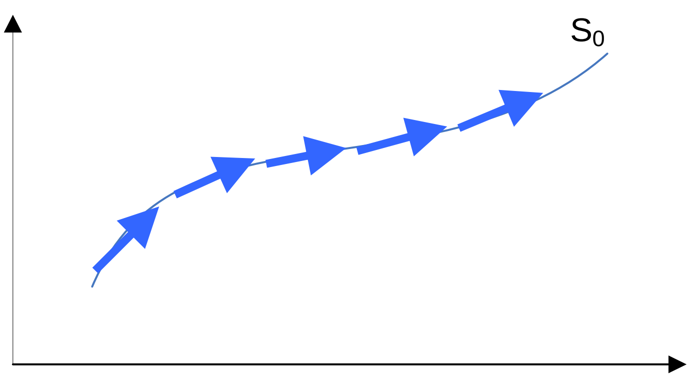
Risk scenarios – Success scenario



- Example of success scenario – chemical process industry
  - 1. Feed in raw material to reactor
  - 2. Stir and heat the mixture
  - 3. Reaction
  - 4. Separation
  - 5. Cooling



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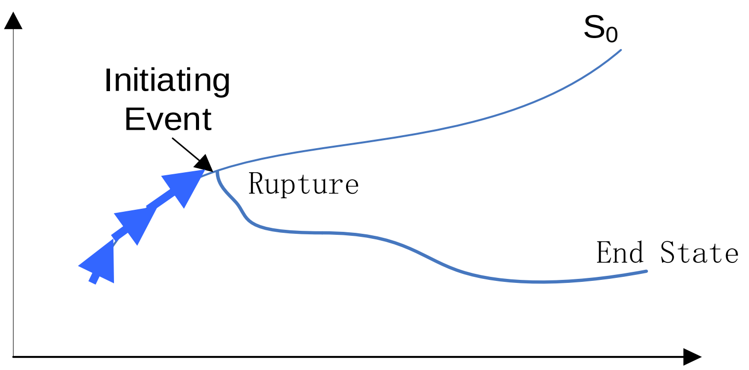
Risk scenarios – Start and ending

- Starts with an Initiating Event – triggered by a hazard
  - Flood occurs, technical failure of a component, wrong input material, etc.
- Ends in an End State where it is possible to estimate the negative consequences

  A fatality, 10 000 $ economic loss

1. Feed in raw material to reactor
2. Stir and heat the mixture
3. Reaction



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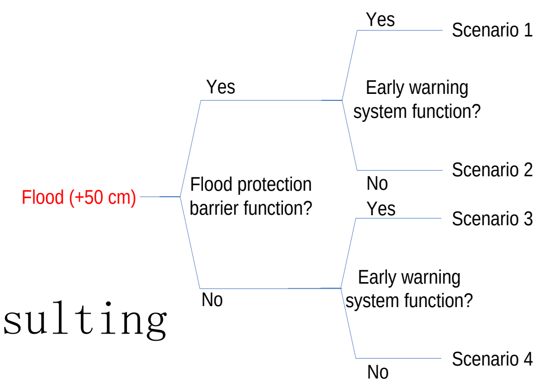
Risk scenarios – Branching



- Each Initiating Event may lead to a set of resulting risk scenarios
  - Can be structured using an event tree (similar to a decision tree)
- How a risk scenario evolves is determined by conditions in the branching points
  - Does flood protection barrier function?
  - Does early warning system function?
- Each branch is a specific risk scenario – represents our uncertainty about the future

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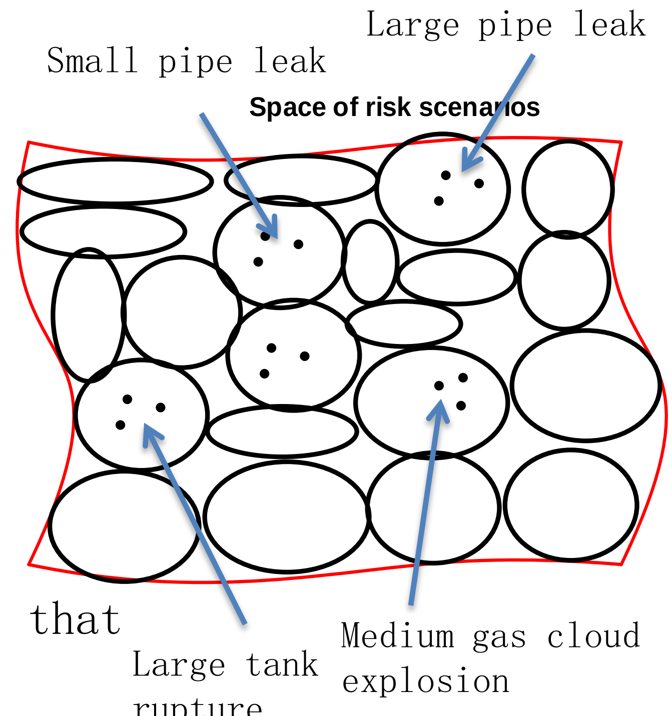
Risk scenarios

- How many scenarios exist in reality?
  - Pipe leak, 5 cm^2, at 2.00 PM
  - Pipe leak, 5 cm^2, at 5.45 PM
  - Tank rupture, 15 cm^2, evening
  - Tank rupture, 15 cm^2, day
  - …
- Impossible to describe all in detail!
- No. of scenarios must be reduced
  - By selecting a *finite set* of scenarios that *represent* everything that may happen



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Risk scenarios

- ”Scenario explosion” quickly arise
  - E.g. 20 incidents, 4 incident outcomes, 8 wind directions, 8 wind speeds, 5 weather stabilities, 4 population patterns, EWS may work or not
  - No. scenarios: 20 x 4 x 8 x 8 x 5 x 4 x 2 = 200 000…
- Goal when a representative scenarios are selected/described
  - *Level of detail* should be *suitable*
  - The set of risk scenarios included should be *complete*
  - Scenarios should be *disjoint/non-overlapping*
  - Risk level should neither be over- nor underestimated

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Risk scenarios – Suitable level of detail

- The risk scenarios should be specified with *enough details* to allow for *sufficiently accurate* consequence estim
  - Subdivision of scenarios may be need
- …at the same time, the number of scenarios must be ”manageable” considering available resources
  - Clustering of scenarios may be neede

Flood (+50 cm)

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Risk scenarios – Completeness

- All scenarios that can happen should be *covered* by the risk assessment – otherwise the risk is underestimated
- This does NOT imply that a risk analysis can "predict" what will *actually* happen *in detail*
  - Example: The attack on 9/11
- But it could include *the type of risk scenario*
  - "A medium-sized airplane colliding with WTC"
- Difficult to achieve completeness in practice and difficult to know if one succeeds

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Risk scenarios – Completeness

- Recommendations on how to address the completeness issue?
  - Use a structured method for risk identification & historical data
  - Put together a diverse group of knowledgeable participants/analysts
  - Stimulate creativity and collective imagination
  - Compensate for possible incompleteness – by using safety margins, conservative assumptions, etc.

Risk scenarios – Non-overlapping scenarios

- Scenarios should not overlap (should be mutually exclusive) – why?
  - May lead to "double-counting" when aggregating the scenarios

- Appropriate scenario division
  - "A Richter magnitude smaller or equal to 4"
  - "A Richter magnitude of between 4 and 7"
  - "A Richter magnitude greater or equal to 7"

- Inappropriate scenario division:
  - "A Richter magnitude smaller or equal to 5"
  - "A Richter magnitude of between 4 and 7"
  - "A Richter magnitude greater or equal to 6"

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Risk scenarios – Strategies to reduce no. of risk scenarios

- Exclude scenarios with non-significant consequences
  - E.g. if the interest is on how the public is affected then all scenarios where only employees are affected can be excluded
- Combine/cluster scenarios that are redundant or very similar
  - E.g. pipe leak from different pipes can be clustered if the consequences would be the same-ish

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Risk scenarios – Strategies to reduce no. of risk scenarios

- Only use a few different values on parameters that can vary
  - E.g. if the hole size can vary continuously from very small (1 cm^2) to very large – e.g. choose two hole sizes 20 cm^2 and 80 cm^2
- Parameters with a minor effect on the consequences can be fixed at their mean values
  - E.g. a outside temperature of 0 °C gives almost the same consequences as 30 °C, therefore fix it at 15 °C

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Likelihood and consequence estimations

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Likelihood estimations

(1) “Extremely unlikely”
(2) ”Very unlikely”
(3) “Unlikely”
(4) “Likely”
(5) “Very likely”

(1) Extremely unlikely – less than 1 per 1000 years
(2) Very unlikely – 1 per 100 years to 1 per 1000 years
(3) Unlikely – 1 per 10 years to 1 per 100 years
(4) Likely – 1 per year to 1 per 100year
(5) Very likely – more than once every year

- Different scales or measures can be used
  - Qualitative ranking scale
  - Semi-quantitative ranking scales
  - Quantitative
- Estimations are based on:
  - Historical data/statistics, Logical models & Expert judgements
- Estimations for a “scenario cluster” – e.g. flooding of between 2-4 m water levels – should consider the *total likelihood* for the cluster

Frequency: 0,5 times per year
Probability: 10% sprinkler system success

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Consequence estimations

- The extent to which the value basis is affected
- Different type of scales can be used (similar t likelihood est.)
  - Natural scales (typically quantitative)
  - Constructed scales (typically qualitat
- Typically simulation models, calculation expert judgments and historcal data are

No. Fatalities,
Amount of economic loss (Euros)
Area of polluted land (km^2)

Insignificant	Minor issue of little concern to community
Minor	Isolated case, some small disruptions
Moderate	Requires attention, inconvenience
Major	Requires urgent attention, impact days
Catastrophic	Wide damage lasting weeks, impact high

Consequence estimations

- When consequences for a scenario cluster is estimated – the *average consequences* of the cluster should be estimated
  - Give rise to a *representative risk level* (i.e. neither under- nor overestimated)
  - Example: If the scenario is defined as a flood of between 2 and 4 m water levels above average – the consequences for a 3 m flood should be estimated

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Risk presentation and evaluation

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Risk presentation

- Difficult to use the information from a risk analysis *directly* – list of scenarios
- Risk presentation concerns facilitating understanding and evaluation

Scenario	Likelihood	Consequence
1	0,02	10
2	0,05	5
3	0,01	20
…	…	…
100	0,001	33

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Risk presentation

- Many ways to present risk
  - Point value/Index
  - Matrix
  - Graph
  - Map
  - Etc.
- Major risk contributors and uncertainties can/should also be presented

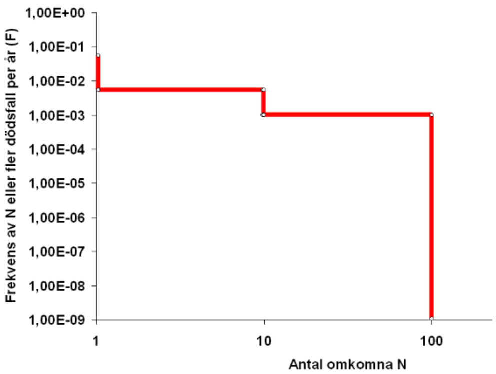
Expected value:

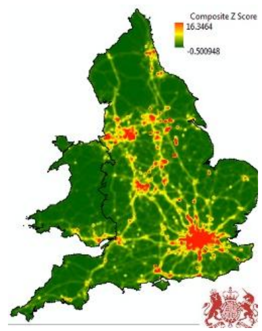
$$E(C) = \sum_i P_i \cdot C_i$$

3 x 3 Risk Matrix

LIKELIHOOD			
Likely	Medium Risk	High Risk	Extreme Risk
Unlikely	Low Risk	Medium Risk	High Risk
Highly Unlikely	Insignificant Risk	Low Risk	Medium Risk
	Slightly Harmful	Harmful	Extremely Harmful

CONSEQUENCES





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Risk evaluation

- Risk analysis concerns obtaining an as well-informed estimate
  of risk levels as possible
- Risk evaluation concerns comparing these results with risk criteria to determine whether the risk and/or its magnitude is acceptable/tolerable
- Various ways of presenting risk facilitates risk evaluation and decision-making

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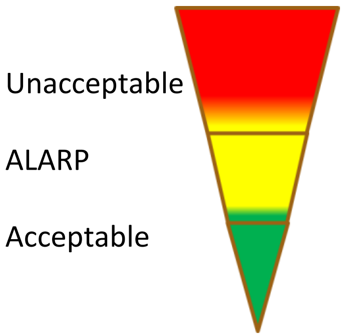
Risk evaluation

- Several approaches exist to risk evaluation
- Comparison of the risk level to some risk acceptance criteria
  - But the risk levels is rarely the only thing that matters
- Comparison of pros and cons (utility-based)
  - A risk is acceptable if its benefits are larger than its costs
- Consideration of people's risk perception



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Summary

- What is risk and risk assessment?
- Why perform risk assessments?
- Challenges for risk assessments
- A framework for risk assessment

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K-FORCE

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Thank you
for your attention

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Knowledge **FO**r **R**esilient so**C**i**E**ty

Finding and describing risk scenarios

- Identify initiating events and consider what might happen due to them – e.g. event trees

- Identify important end states and identify risk scenarios that can lead to them, e.g. fault trees

- Find critical mid-states and investigate how the system can end up there, and try to determine what can happen as a consequence of the mid state – e.g. Bow-ties, HAZOP, FMEA, What-if, etc.