Engineering Risk Management
Lecture 1

Introduction to engineering and managing risks

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Prof. dr. ir. Genserik Reniers

- MSc. in Chemical engineering
- Ph.D. in Applied Economic Sciences
- Full professor at TUDelft & UAntwerpen (Chair on Safety of hazardous materials)

- Expert in

- Domino effects in the Process Industries
- Cluster safety and security culture
- Safety and security collaboration
- Uncertainty analyses and game-theory
- Systemic risks in the process industries
- Safety and security prevention and economics

Top Contribution Themes

w.r.t. Research on Safety of Hazardous Materials

- **Collaboration** and cross-plant technology, -management, -HF and -safety culture in industrial clusters
- **Escalation** of accidents (so-called 'domino effects') and **systemic risks**
- Safety and security of **hazmat transportation**
- **Safety staffing levels** in relation to safety critical tasks, and optimization of **evacuation decisions**
- **Performance management** in relation to safety and security
- Prevention- and **safety economics**

Scientific literature contributions

to Safety of Hazardous Materials
(Books: see pictures, Papers: see databases)

- **Sustainable industrial chemistry** (Wiley VCH)
- **Engineering Risk management** (De Gruyter)
- **Total Respect Management** (LannooCampus)
- **Domino effects in the process industry** (Elsevier)
- **Game theory in the chemical industry** (Springer)

Editorial tasks (keeping up with current research in the field)

Available info/literature for the course

- **<u>OBLIGATORY COURSE: "Engineering Risk Management" 2nd Edition (2016)</u>**

  (De Gruyter, Berlin; authors: Meyer & Reniers)

  (normal price: 70€, one-time reduced price: 50€ → list!)

- **<u>RECOMMENDED (NOT OBLIGATORY):</u>**
  - Book: "Operational Safety Economics" (2016) (Wiley-Blackwell, London; authors: Reniers & Van Erp)
  - Boek (IN DUTCH): "Total Respect Management" (2013) (LannooCampus, Leuven; authors: Blokland & Reniers)
  - Boek (IN DUTCH): "Absolute veiligheid. Utopie of niet?" (2016) (ShopMyBooks, Puurs; author: Reniers)

- <u>Slides:</u> intranet ; literature on risk and safety mgt: library
- Extra information: https://www.uantwerpen.be/en/rg/engineering-management/research-teams/safety-and-security/

Books

- Obligatory:

- Recommended:

Exam

Written exam:

- Partially closed book exam (50%) – 1,5h

- Partially open book exam (50%) – 1,5h

In the open book part of the exam, you are allowed to use the Book "Engineering Risk Management", 2nd Edition, and all your notes that you have taken during class (no other books; no photocopies!)

Questions?

Preferably via mail:

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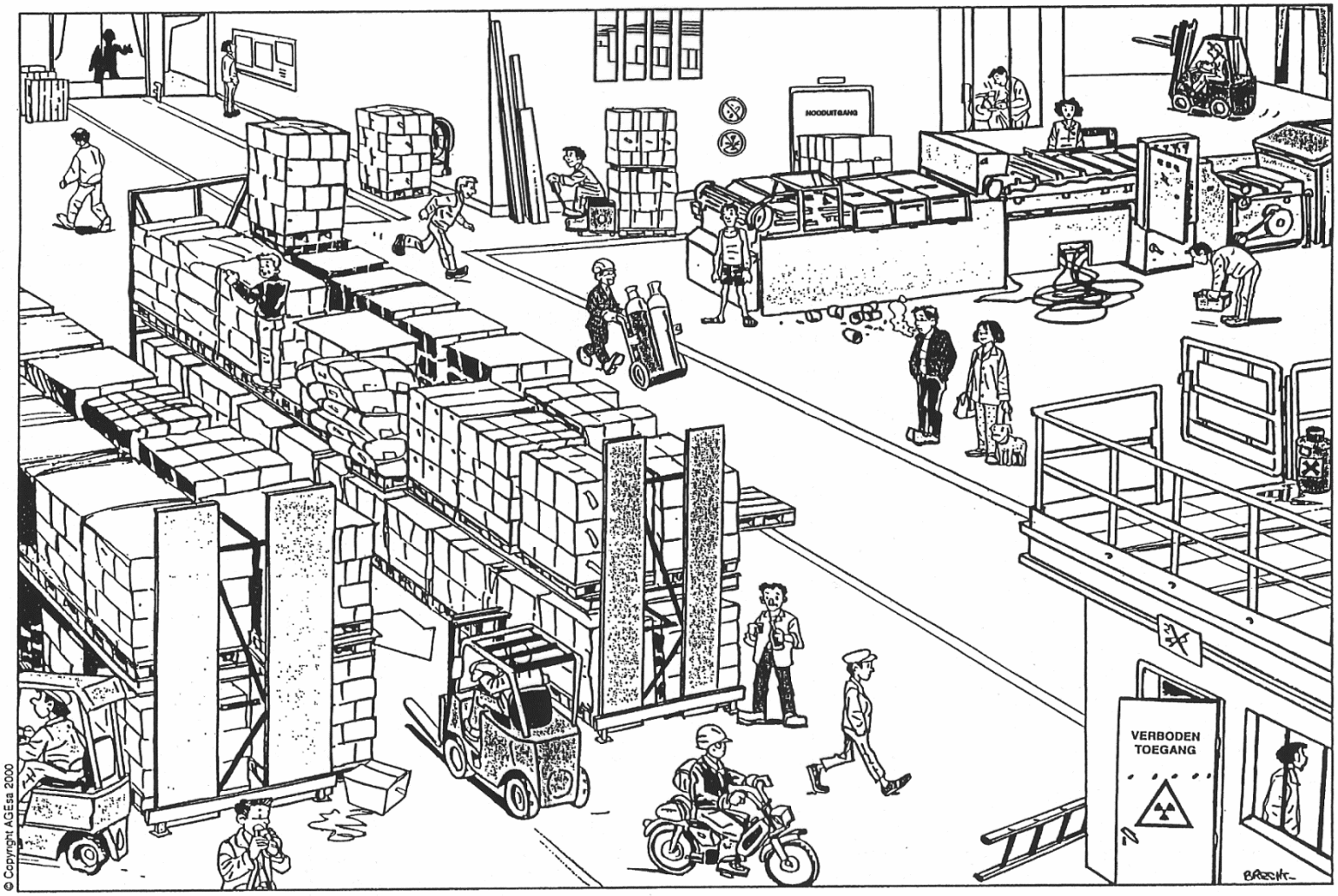
- Uantwerpen, City campus, office at the chemistry lab (Koningsstraat)

Why Engineering Risk Management?

- What is ERM?
- Why do we need it?

"Zoek de risico's"

Ref. 01C 2



NAAM : ..... Voornaam : ..... Afdeling : .....

Hazards and their management

1. Identify the hazards in this working place (different domains are possible: safety, health, environment, security, quality, ethics)

2. Determine the direct causes: this is the first answer to the question "why does this hazard exist?"

3. Determine the **in**direct causes: answers to the following (2nd, 3rd, etc.) "why" questions → search for the 'root cause'

4. Determine prevention measures for the direct causes? For the indirect causes?

5. Classify prevention measures (if possible) (make a systematic inventory)

Hazards and their management

Hazard	Direct cause	Indirect causes	Prevention measures

Conclusion: the usefulness of a systematic way to manage hazards

Some examples from the exercise:

- Establish responsibilities
- Train and educate employees
- Plan preventive controls and audits
- Policy in case of non-compliance
- Carry out risk assessments
- Plan and execute preventive and protective measures
- …

Acquaintance

- Background?
- Knowledge about safety and security management?
- Expectations of this course?
- Why? How?
- What (contents)?

Contents

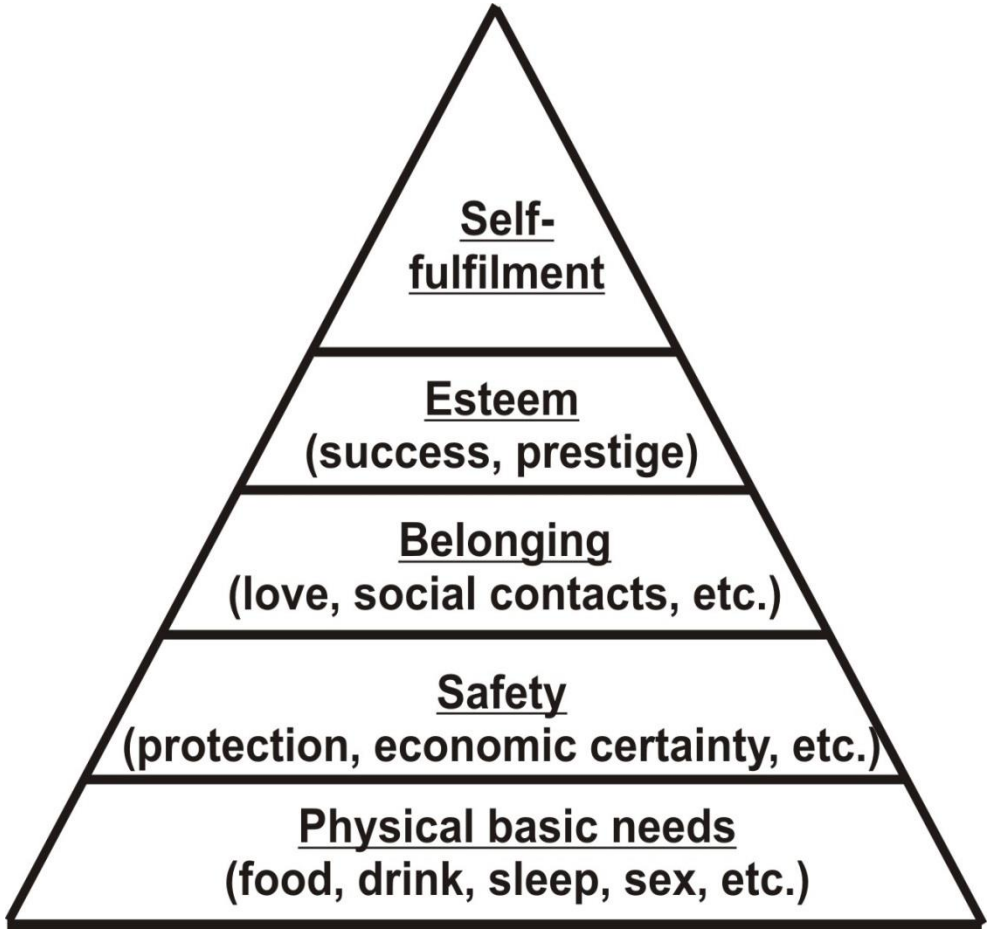
1. **Risk management is not only a matter of financial risk**
2. Introduction to engineering and managing risks
3. Risk Management Principles
4. Risk diagnostic and analysis
5. Risk treatment/reduction
6. Event analysis
7. Major industrial accidents and Learning from accidents
8. Crisis management
9. Economic issues of safety
10. Risk Governance
11. Examples of practical implementation of risk management

Risk is of all times

- Major accident – example: is investing in risks worthwile, for society and for business?

- History of risks in a world perspective:
  - 2500 BC: Chinese
  - 1600 BC: Egyptians
  - 400 BC: Greeks
  - 1 AD: Romans
  - 1500 AD: Continental Europeans
  - 1700 AD: English
  - 2000 AD: Americans and Europeans

Why is risk of all times? – Human needs!



Analytic and systemic

- Systemic thinking: the whole is primary and the parts are secondary (dynamic, circular, complexity, resiliency)

- Analytic thinking: the parts are primary and the whole is secondary (static, linear, simple cause-consequence relationships, additivity of elementary properties)

Risk management – to put it in simple terms

- Put out a manager's fires, and you help him for a day. Teach a manager fire prevention, and you help him for a career.
- Being smart about taking chances
- Determining predictive data
- Never-ending process!

Failure of risk management?

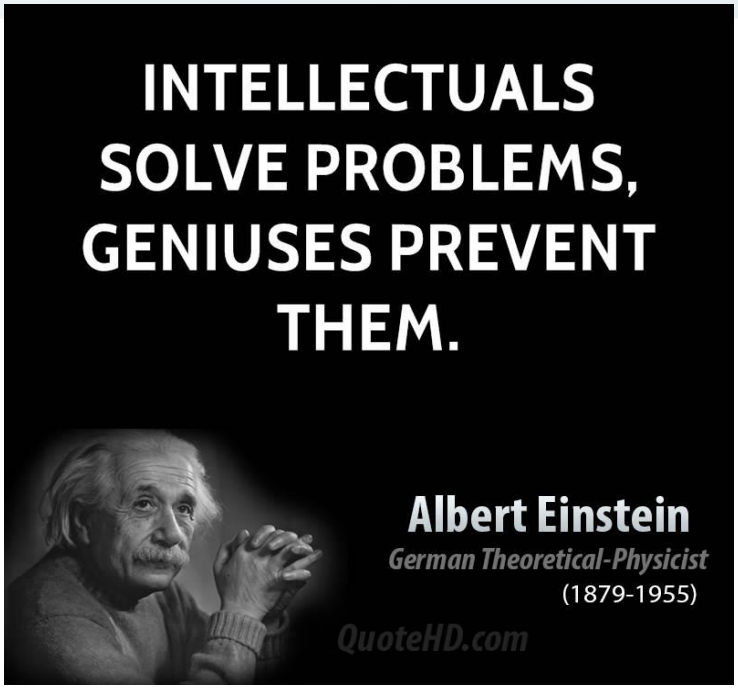
- Failure to measure and validate methods as a whole or in part
- Use of factors in models that are known not to be effective
- Lack of use of factors in models that are known to be effective

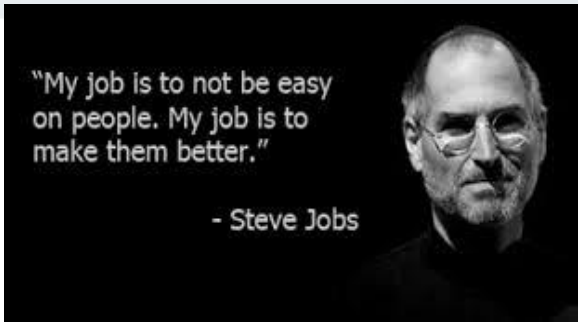
Risk management assures that:

- Objectives are more likely to be achieved
- Unwanted events will not happen or are less likely to happen

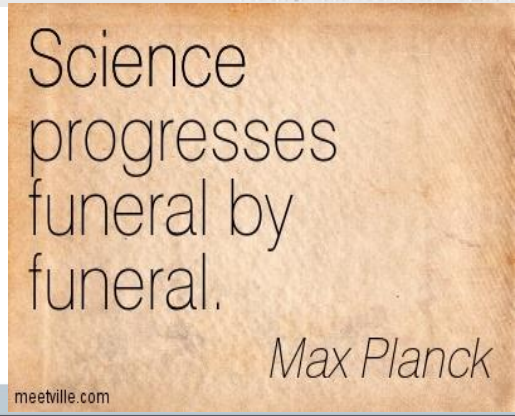
However…watch out:
Not everyone is a 'Safety thinker'!

'Safety thinkers'





No 'Safety thinkers'



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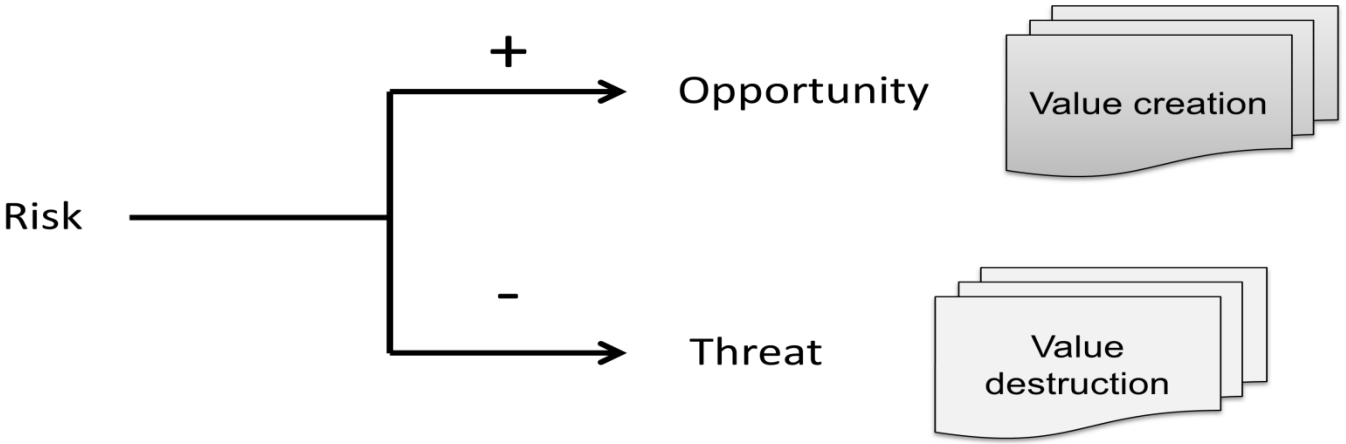
The Concept of Risk

- Negative risks are weighed against individual freedom, personal pleasure, group advantages, financial gains, etc.
- Everyone makes dozens of costs/benefits decisions daily (actually potential negative consequences/potential positive consequences) (choices contain risks!)
- But what is a 'risk' (what are the types of risks, are there concepts to deal with them, etc.)?
- General definition of **risk** (may be + and –):
  "**The effect of uncertainties on achieving objectives**"
  (cfr. ISO 31000:2009)

Negative or positive risk



Living with risk

People selectively reduce or increase their exposure to risk:

Homo prudens >< Homo aleatorius

Safety literature is aimed at homo prudens and ignores or seeks to reform homo aleatorius.

However, the more one knows about risks, the more one realizes how much there is to know!

→ The complex and multidisciplinary field of risks and risk management should be jointly investigated by scientists, engineers, psychologists, social scientists, economists, etc.

Risk in modern society

Key issue in modern technological development:

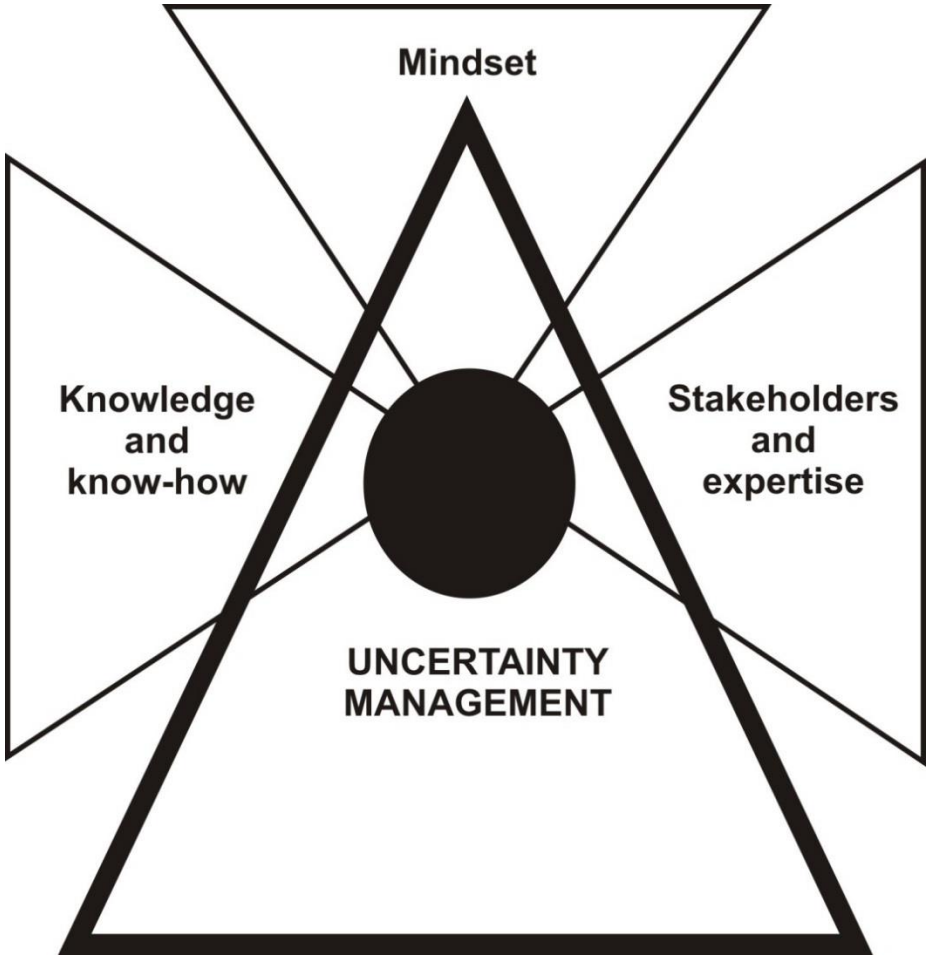
Governments, regulators, industrial bodies, etc. propose and develop techniques to identify the risks, assess potential risk levels, and define acceptable levels of risk.

However, expert judgement on consequences and probabilities is not the same as public (NON-expert) judgement!

Moreover, the way in which the risks are communicated to the public has an impact on risk perception

E.g.: Number of victims from 9/11 = 3000? No! There were 5500 victims! Why?

Risk management – Uncertainty management?



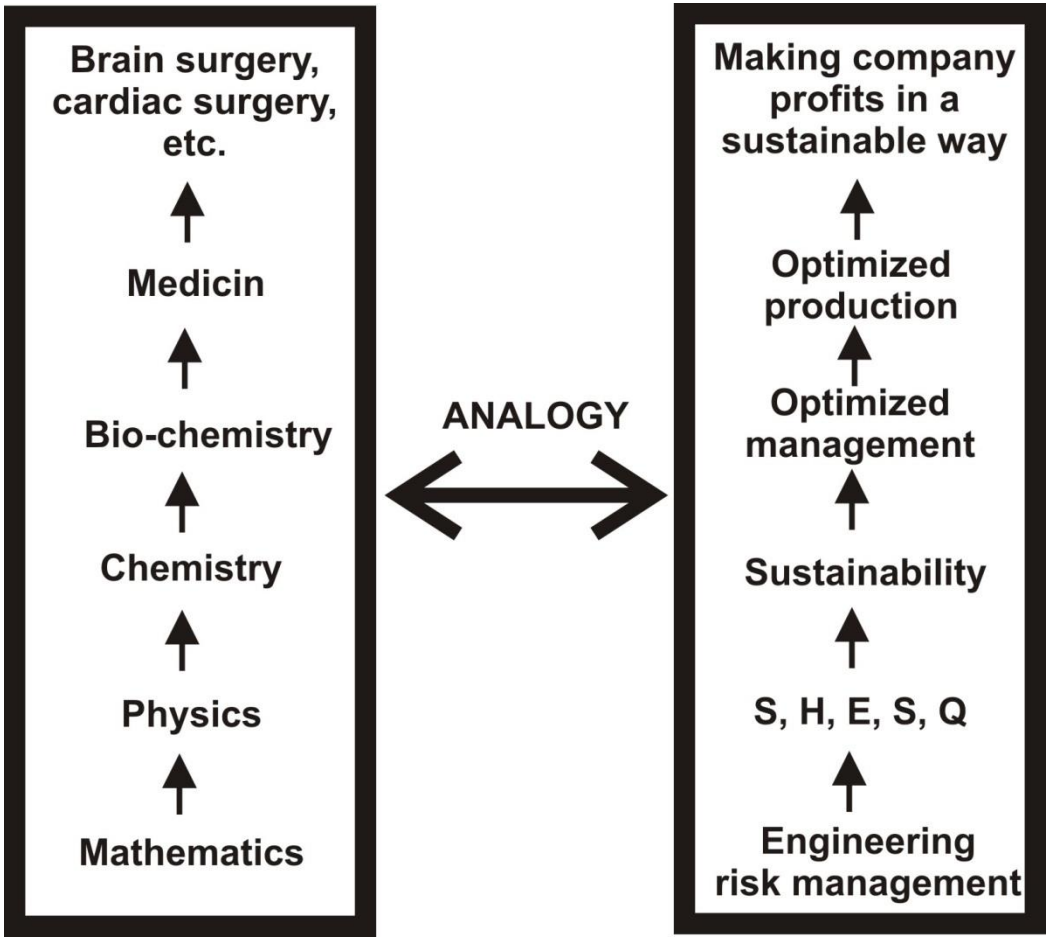
Uncertainty management

- Knowledge and know-how: past, present and future data and information, risk taking-, risk averting- and risk neutral items, laws and regulations, rules and guidelines, best practices and ideas, People, Procedures, technology

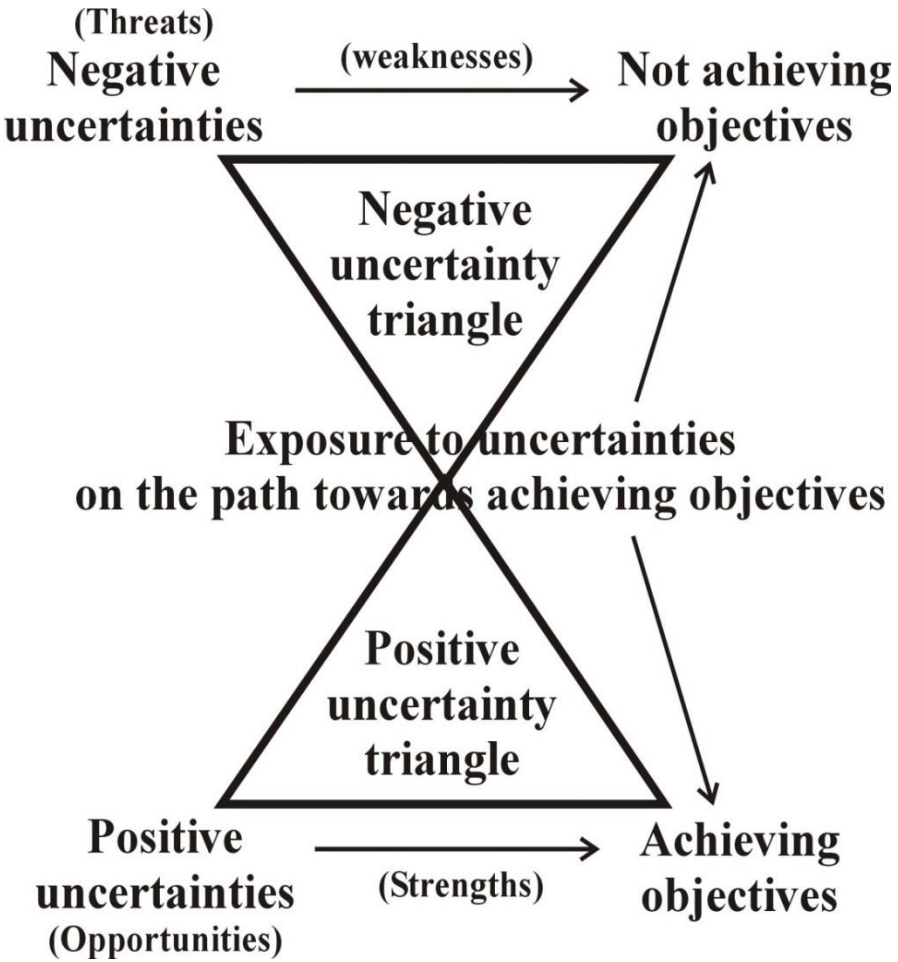
- Stakeholders and expertise: business, authorities, academia, other stakeholders, different disciplines

- Mindset: linear and circular, linear and non-linear, short term and long term, in the box and out of the box, etc.

Exact sciences and risk management analogy



The complexity of risks and uncertainties - Uncertainty sandglass



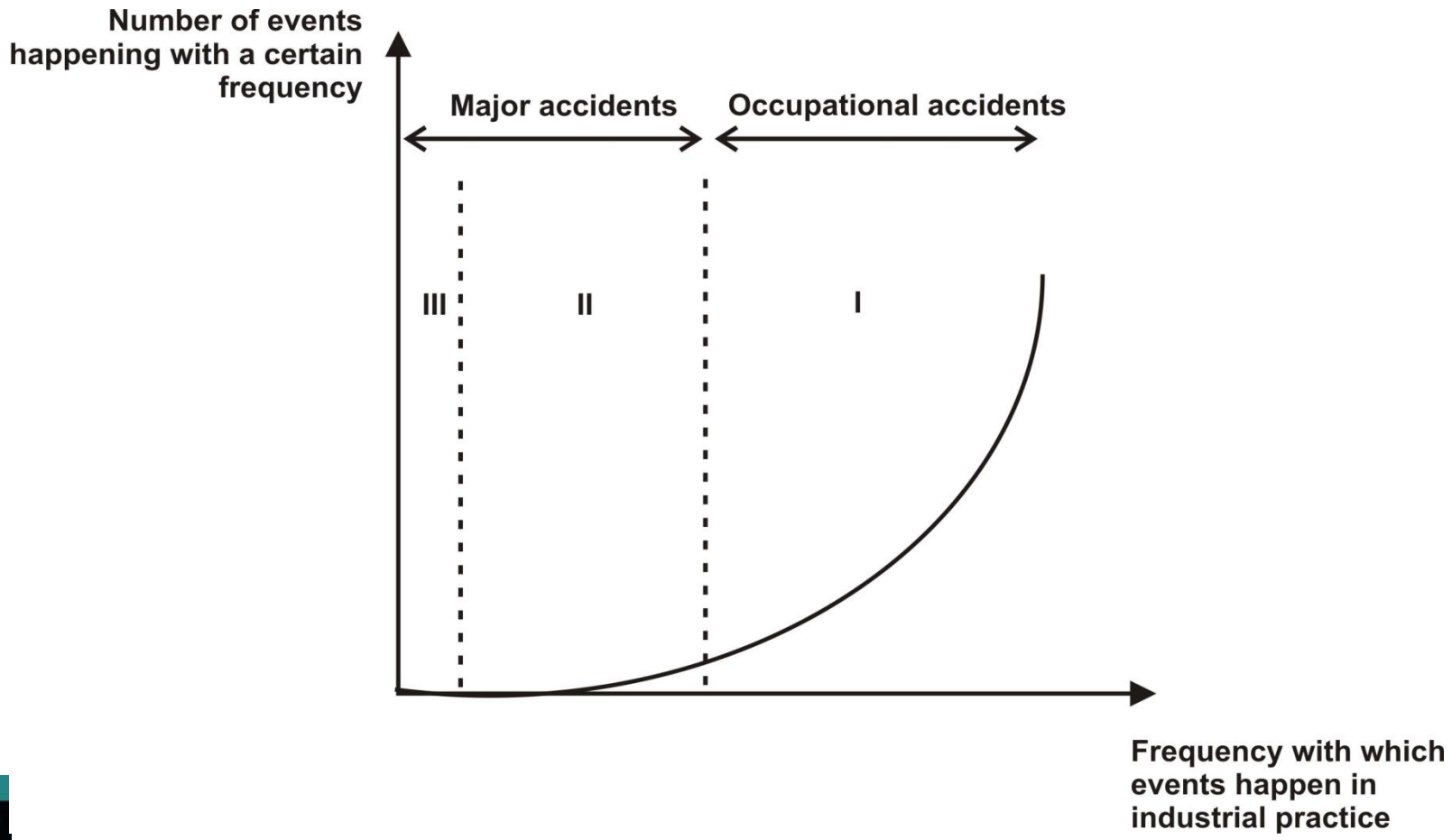
Negative Risk-TRIAS: Model-triangle

Risk =

Hazard ----------→ Loss

Exposure

Different types of uncertainties/risks



Another way of explaining the types of uncertainties/risks: “known/unknown”

	Knowledge	Lack of Knowledge
Open mind	Known Known	Known Unknown
Closed mind	Unknown Known	Unknown Unknown

Different types of risks

Type I

Different types of risks

Type II

Different types of risks

Type III

The Concept of Risk

Ultimate cause of 'safety and security' in society:
the existence of a variety of risks

"Risk": from the Greek word 'riza', which means 'cliff'
→ From individual uncertainty towards collective insurance

Risk (16th century): "a financial venture in a commercial undertaking" (hence, + and -)

Now: 'risk society' (U. Beck, 1986)
(authorities and government pre 1950s: division of wealth and poverty;
From 1950s on: authorities and governments: division of risks)

Focus was re-located from physical hazards towards social hazards

Definitions

Hazard:

The potential of a human, machine, equipment, process, matrial, or physical factor to lead to an unwanted event possibly causing harm to people, environment, assets, or production.

hence: a hazard is a disposition, condition or situation that may be a source of an unwanted event leading to potential loss.

Examples:

- fryer in use: hazard = *heat*
- toxic product: hazard = *toxicity*
- storage of products that look alike:
  hazard = *looking alike*

Definitions

Exposure to a hazard:

contact between hazard and someone (or something) that may suffer loss

Examples:

- person working with fryer
- person working with toxic product
- Order by client of one of the look-alike products

Definitions

Loss: Depreciation of something that humans value, as a result of one or more hazards.

Different types of loss exist: human loss [HARM] (physical, psychical), material or organizational loss [DAMAGE] (equipment, surrounding, product, function disturbance, quality deviations, etc.)

Examples:

- Burns
- Intoxication
- Xrong delivery to client

Definitions

Risk (-): the possibility of loss (injury, damage, detriment, etc.) created by exposure to one or more hazards. The significance of risk is a function of the likelihood of an unwanted event and the severity of its consequences.

Hence: a risk can be regarded as a hazard which has been quantified

→ risk implies uncertainty and hence, implies a likelihood (frequency, probability, or qualitative expression)

Examples:

- probability of childern having burns with a certain degree
- probability of worker being intoxicated with a certain severity
- 10,000€ claim by clients over a certain period of time

Definitions

Probability: expresses the likelihood or frequency of a specific event or outcome occurring.
= number of specific events occurring / total number of possible events

[e.g. P(dying) = 1; P(dying at the age of 60) = 0.11(example!)]

Frequency: rate of the occurrence of an event.
= number of occurrences of an event in, for example, a given period of time, a given distance travelled, or a given number of events.

Likelihood (waarschijnlijkheid): qualitative measure of probability and frequency

Risk management

Not all risks can be avoided (risks also result into profits, gains, products, etc.), hence risks should be controlled and managed

Examples:
Adult+ fryer = small risk
Child + fryer = large risk

Trained employee with toxic product = small risk
Non-trained employee with toxic product = large risk

Computer-operated warehouse = small risk
Manually operated warehouse = large risk

→ Managing risks adequately is very important!

Simplified interpretation of (negative) risk

- Risk = description of situation or state; hence it is an abstract concept, and it cannot be felt by human senses

- Risk can be measured or estimated using mathematical formulae: most used formula:

$$R = L.C$$

Simplified interpretation of (negative) risk

- More elaborated: R = L.C = (N.T/Pre).(D/Pro)

  The likelihood of occurrence L depends on:
  - N: number of set targets
  - T: average exposure time of each target at risk
  - Pre: prevention implemented to reduce N or T

  - Consequences C are function of:
  - D: "crude" hazard of the situation
  - Pro: level protection implemented in the light of this hazard

Simplified interpretation of (negative) risk – reducing risk?

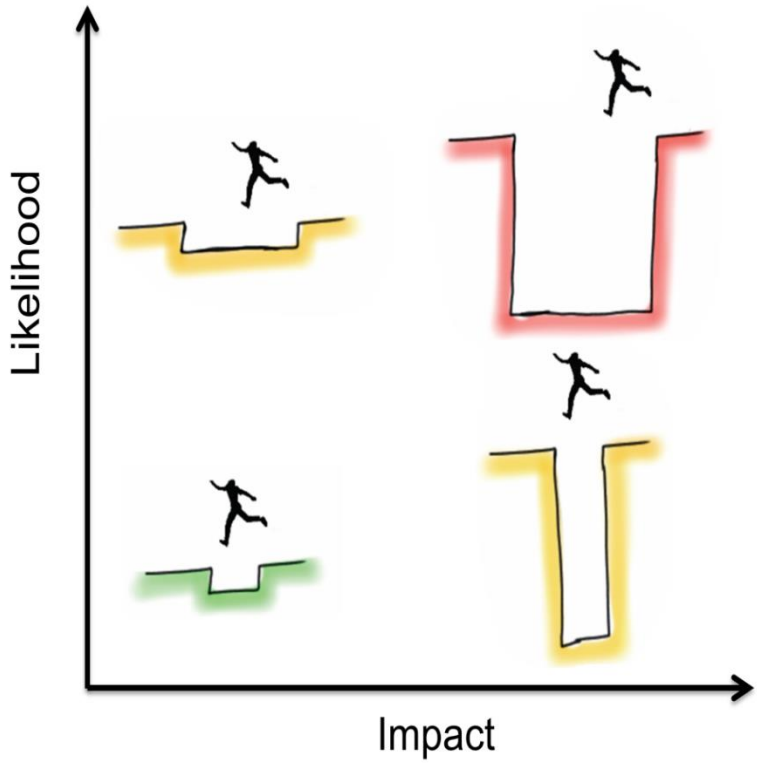
Changing the risk by reducing the occurrence of its components and/or their severity means to answer to the following questions:

- Is it possible to reduce the number of exposed targets (N)?
- Is it possible to reduce the time the targets are exposed to the hazard (T)?
- Is it possible to increase the prevention measurements (Pre)?
- Is it possible to reduce the hazardousness (D)?
- Is it possible to increase the level of protection (Pro)?

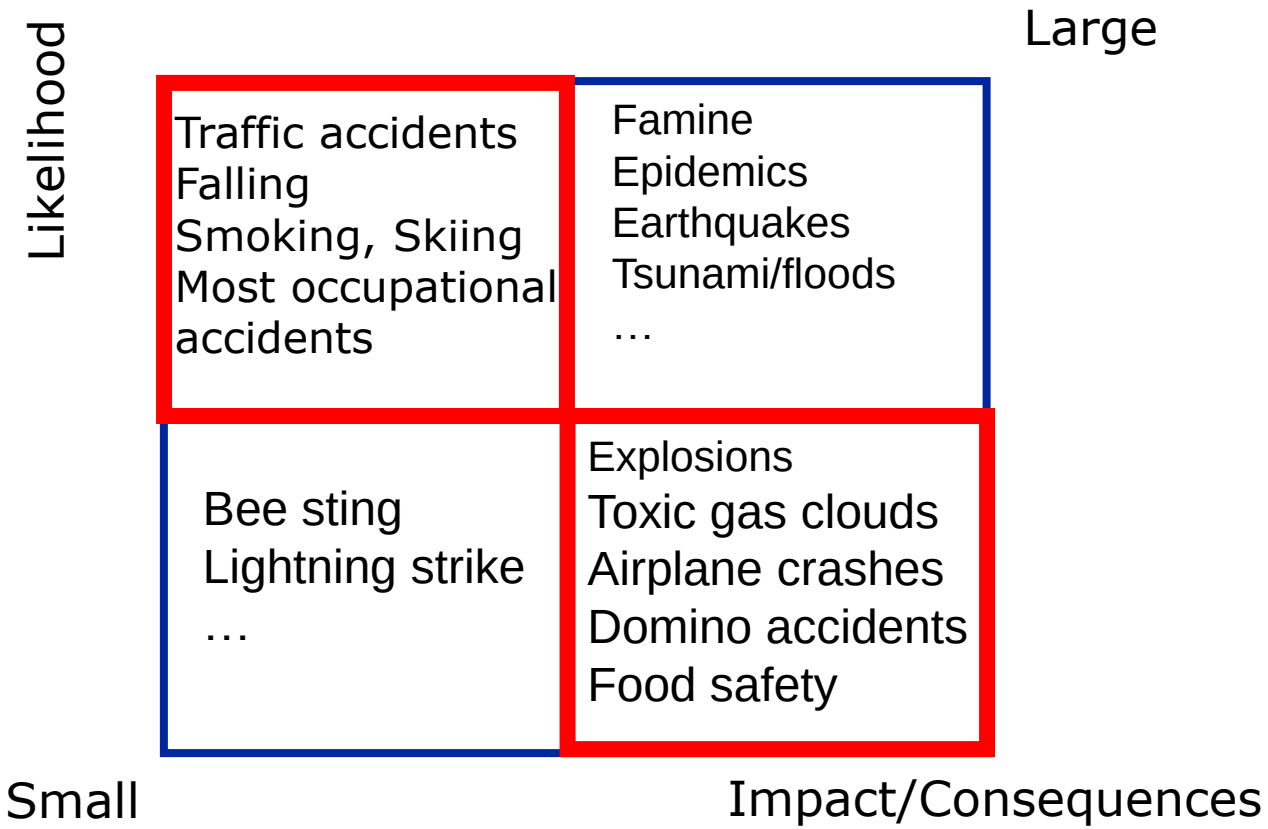
Zero-risk does not exist, except:

- If the hazard is zero or non-existent.
- If there is no exposition to the hazard.

Matrix representation of risk calculation: different possibilities



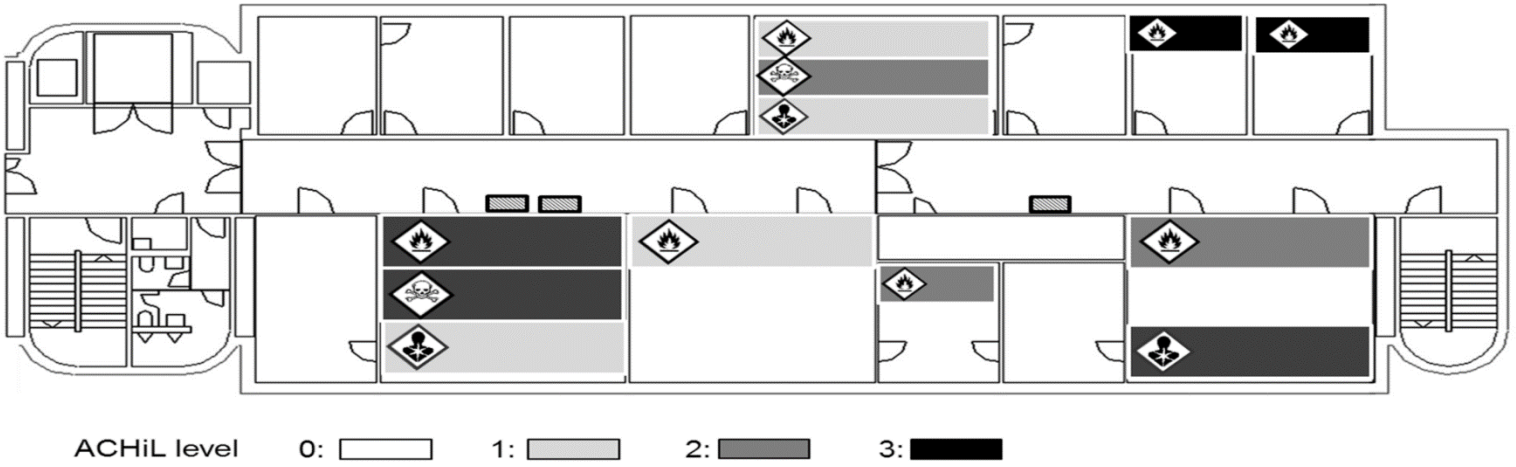
Operational risk examples



Hazard and risk mapping

- Purpose: to provide people with the information on the range of possible losses/damage and the accident prevention activities
- Resident-educating type: main objective is to inform the residents living with the damage forecast area of the risk or danger
- Administrative information type: main objective is to use as basic material for administrations to provide disaster prevention services, and to take decisions on LUP

Hazard and risk mapping - example



Risk mapping benefits

- to improve your **understanding of the risk profile** and your ability to **communicate** about it
- to force you to **think through rigorously** the nature and impact of the risks that have been identified
- to **improve your risk models** by building an intermediate **link between the risk register and the model**
- to **improve your risk register** by basing it on a more transparent and accurate understanding of the system.

Risk Perception and risk attitude

Perception = conclusions and views that individuals reach about issues based on an accumulation of information and experiences from the world in which they live

→ Influenced by personal needs, traits and beliefs, situational influences (social environment, work env.)

2 components: physical perception (very rapid) and cognitive perception (over longer periods of time)

Risk perception and risk attitude

- To put it simple: Risk perception is the way in which people look at risks
- Risk perception a.o. depends on: the degree to which the risk is known or unknown, voluntary or involuntary, acceptable or avoidable, threatening or attractive, controlled or uncontrolled.
- Influencing perception is influencing risk taking/averting behavior
- Engineering risk management improves the perception of reality, hence influences risk taking/averting behavior

Problem surrounding the perception of risks

The overall probability of dying in the Netherlands is $8.3 \cdot 10^{-3}$ per year; in other words 83 out of 10.000 people.

The majority of these 83 people die of natural causes. Only 3.3 out of these 83 people die of non-natural causes.

In total **6000 casualties per year**:

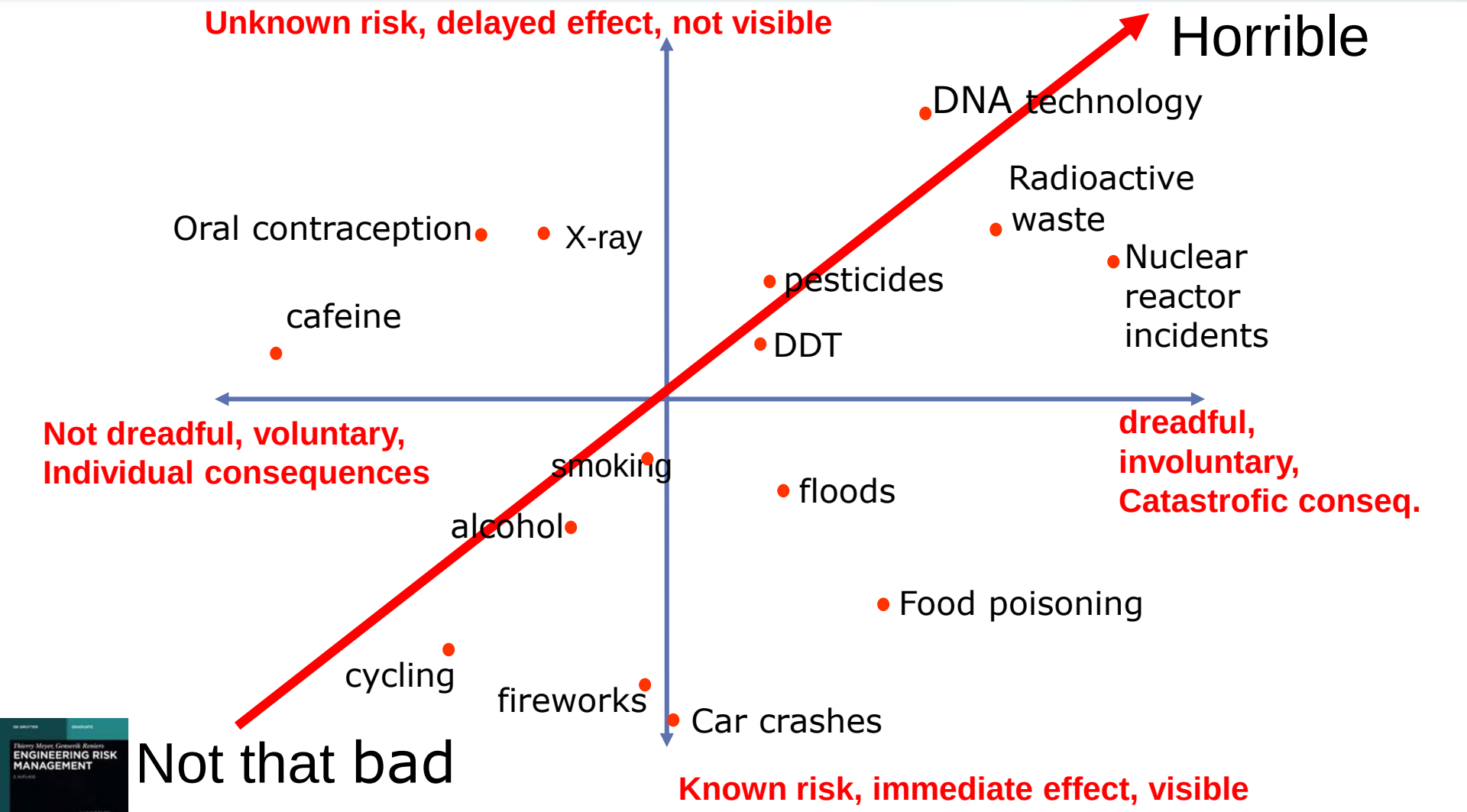
- 2800 at home
- 1600 suicide
- 650 traffic
- 150 murder and assault
- **60 work-related (=1%)**
- 750 other.

Quantifying risk perception?

Comparative views of risks: determined by measured values of frequencies, measured values of consequences, beliefs, attitudes, judgements, feelings, social aspects, cultural values, etc.

Methods to quantify risk perception (psychometric scaling procedures → psychometric paradigm):
magnitude estimation, numerical rating scales, attitude questionnaires, word association, scenario generation techniques

Risk Perception

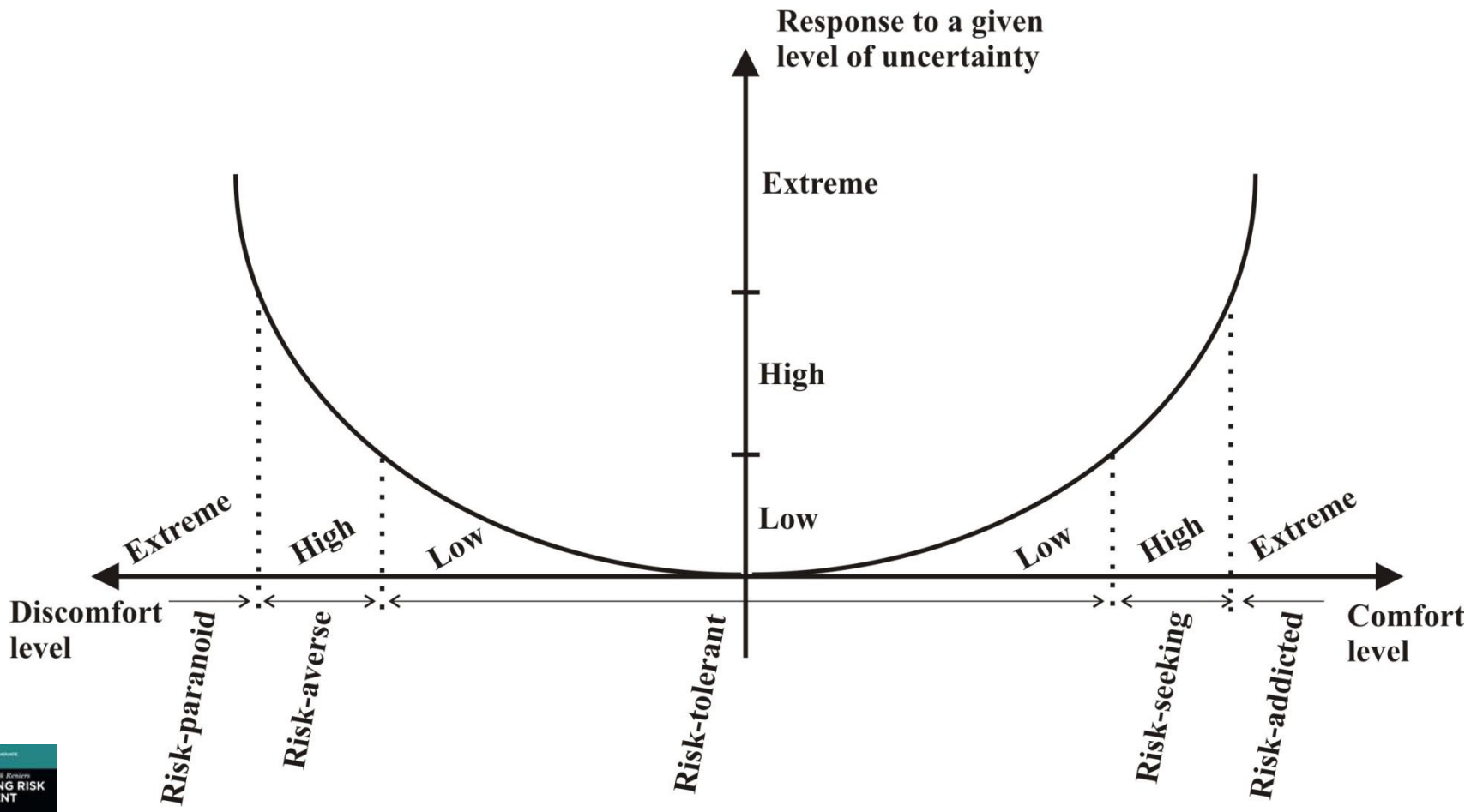


Risk attitude

- Risk attitude can be regarded as the chosen state of mind, mental view or disposition with regard to those uncertainties that could have a positive or a negative effect on achieving objectives.

- Simply put, a person's risk attitude is his or her chosen response to perception of significant uncertainty.

Response to a given level of uncertainty in function of the level of comfort of people



Situational factors modifying the preferred risk attitude

- the level of relevant skills, knowledge or expertise: if high → risk-seeking attitude
- the perception of likelihood (probability of occurrence): if high → risk-averse attitude
- the perception of (negative) impact magnitude: if high → risk-averse attitude
- the degree of perceived control or choice in a situation: if high → risk-seeking attitude
- the closeness of risk in time: if high → risk-averse attitude
- the potential for direct (negative) consequences: if high → risk-averse attitude

KPABC cyclic model

- **K**nowledge → **P**erception → **A**ttitude → **B**ehaviour → **C**onsequences → Knowledge → …

- **Person-based** safety + **behaviour-based** safety