Risk Management in Engineering (49006)

Faculty of Engineering and IT

49006 Outline

- Risk Terminologies
- Risk Management Process, Standards, Plans
- Risk and Reliability Engineering
- Risk Assessment Process and Techniques
- Risk Evaluation and Treatment
- Risk-based Decision Making
- Risk Communication
- Special Topics: Natural Hazards, Domino Effects, and Natechs

Introduction to Risk Management

Risk Management History

- In 2500 BC, Chinese had already reduced risks associated with the boat transportation of grain by dividing and distributing their valuable load between six boats instead of one.
- The ancient Egyptians (1600 BC) had identified and recognized the risks involved by the fumes released during the fusion of gold and silver.
- Hippocrates (460–377 BC), father of modern medicine, had already established links between respiratory problems of stonemasons and their activity.
- Since then, the management of risks has continued to evolve.

Risk Management History

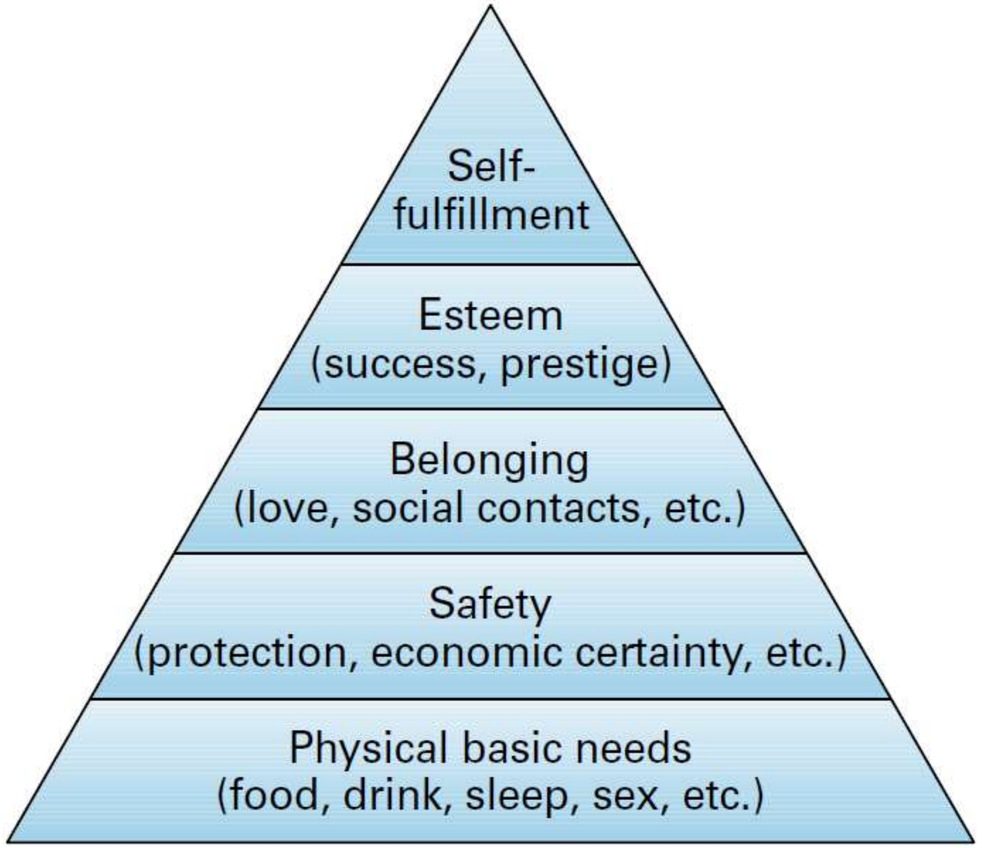
- Pliny the Younger (1st century AD) described illnesses among slaves.
- In 1472, Dr. Ellenbog of Augsburg wrote an eight-page note on the hazards of silver, mercury and lead vapors.
- Ailments of the lungs found in miners were described extensively in 1556 by Georg Bauer, writing under the name “Agricola”.
- Dating from 1667 and resulting from the great fire that destroyed a part of London, the first Fire Insurance Act was published.
- More recent, the essence of risk was formulated by Arnaud as early as 1662: “Fear of harm should be proportional not merely to the gravity of the harm, but also to the probability of the event”.

Risk Management History

- Frank Knight even defines risk in 1921 as a “measurable uncertainty”.
- Today, the word “risk” is used in everyday speech to describe the probability of loss, either economic or otherwise, or the likelihood of accidents of some type.
- Nowadays, the management of risk is a decision-making process aimed at achieving predetermined goals by reducing the number of losses of people, equipment and materials caused by accidents possibly happening while trying to achieve those goals.
- What still remains to be discovered in risk management and risk engineering is rather systemic and more complex.

Human Needs and Safety Importance

- Human needs and wants for certainty can be divided into in five fundamental classes.
- Engineering risk management (ERM) is right after basic needs and is essential for any organization's well-being and for its continuous improvement.



Management Systems

There are two broad categories of management systems:

1. Business Management Systems
2. Risk Management Systems

Business Management Systems

- Business management systems are concerned with developing, deploying and executing business strategies.
- Business management systems specifically aim at improving the quality or business performance of an organization, through the optimization of stakeholder satisfaction, with a focus on clients such as ISO Standard 9001:2008 or extended to other stakeholders (e.g. employees, society, shareholders, etc.) such as the EFQM 2010 Model for Business Excellence or the ISO 9004:2009 Guidelines.

Risk Management Systems

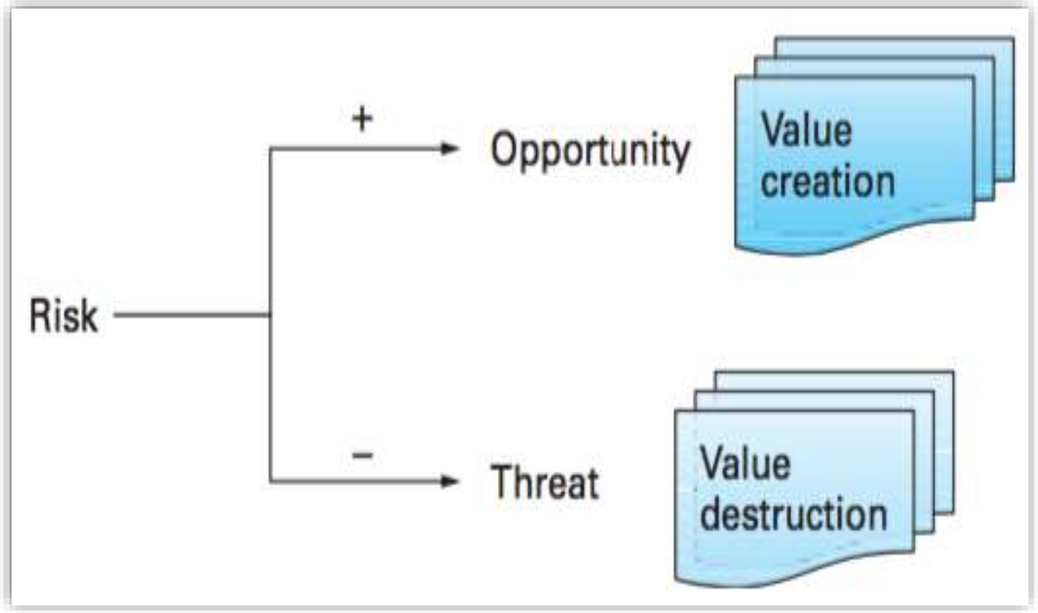
- Risk management systems focus on reducing risks of safety, health, environmental, security and ethical.
- Some of the most popular generic examples of risk management systems are:
  - International standard for environmental management ISO 14001:2004.
  - European Eco-Management and Audit Scheme EMAS.
  - International standard for occupational safety and health OHSAS 18001:2007.
  - International standard for integrity management SA 8000.
  - ISO 45001 Occupational Health and Safety Management Systems Requirements.

Integrated Management Systems

- The boundaries of those two management systems are to fade in recent years. Therefore, integrated risk management models have emerged:
  - Recognizing the positive as well as the negative possible outcomes of risks.
  - Considering all kinds of risks: operational, financial, strategic, juridical, etc.
  - Surpassing compliance and continuous improvement.
  - Canadian Integrated Risk Management Framework (2001)
  - Australian-New Zealand standard AS/NZS 4360:2004, which served as the basis for the development of the generic ISO Risk Management Standard 31000:2009.

Managing Risks and Uncertainties

- A risk is defined by AS/NZS ISO 31000:2009 as “the effect of uncertainties on (achieving) objectives”.
- The definition implies that risks (financial as well as non- financial, technological) are two-sided:
  - Negative risks if the outcome is negative,
  - Positive risks if the outcome is positive.



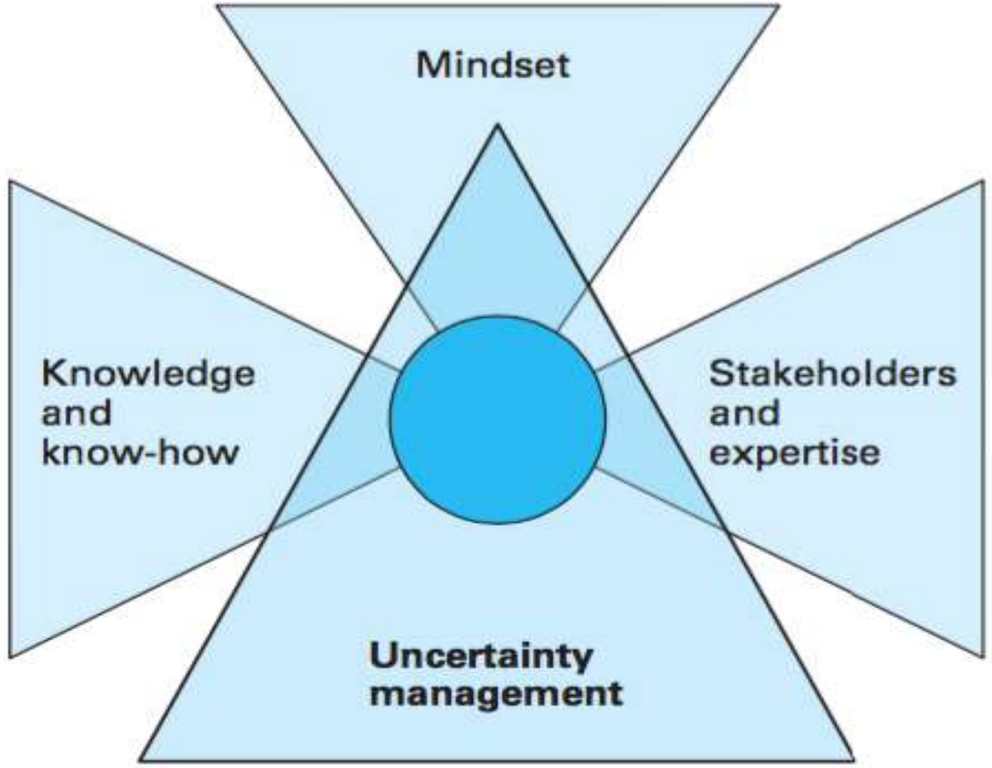
Organizations should manage risks in a way that the negative outcomes are minimized and that the positive outcomes are maximized, this is called risk management.

Managing Risks and Uncertainties

- In current industrial practice, risk management is only focused on negative risks, and only on avoiding losses, instead of simultaneously avoiding losses and producing gains.
- Risk managers have been appointed in organizations mainly to satisfy legislative requirements or because of incidents and accidents that happened within firms; hence the only risks that needed to be managed displayed possible negative consequences.
- Risks should be viewed from a holistic viewpoint, meaning that all relevant stakeholders and experts should be involved in the risk management process.
- The end goal is to use all the right people and means, at the right time, to manage all existing risks in the best possible way, whether the risks are positive or negative, or whether they are known or not.

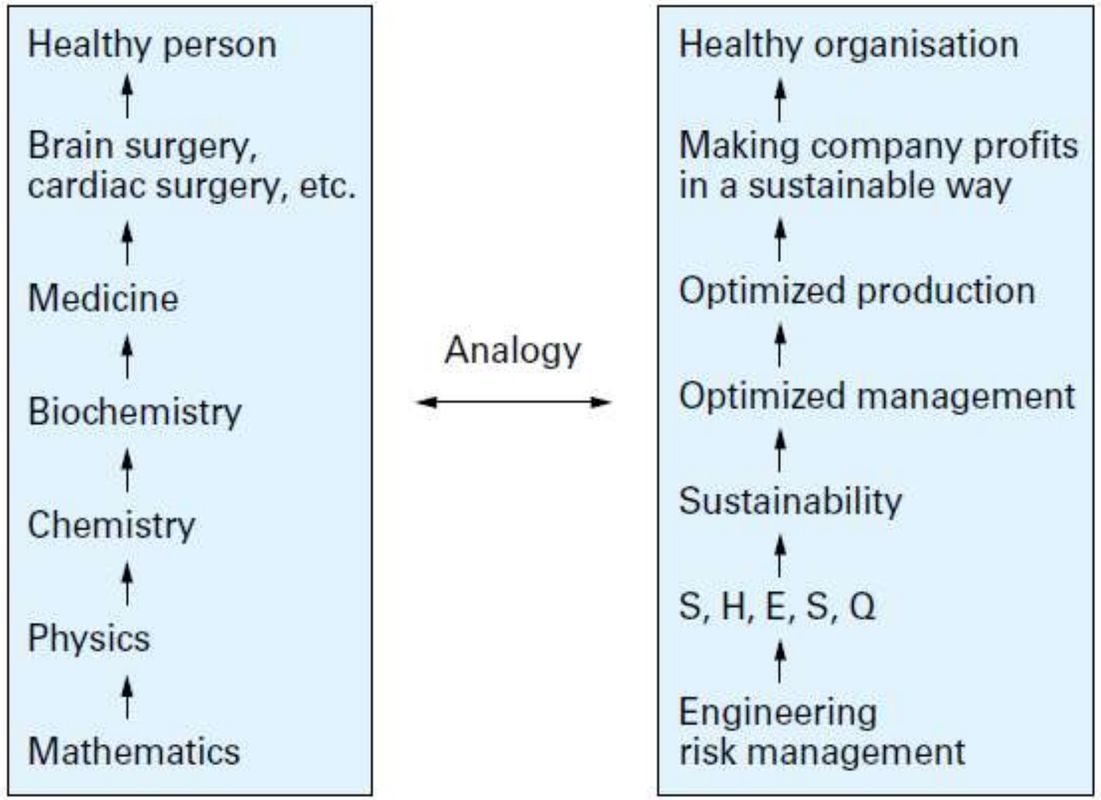
Managing Risk and Uncertainties

- To manage uncertainties efficiently, a composite of three building blocks (knowledge and know-how, stakeholders and expertise and mindset) are necessary.
- The right mindset, enough information and the right people are essential to deal with risks and uncertainties in efficient and effective way.



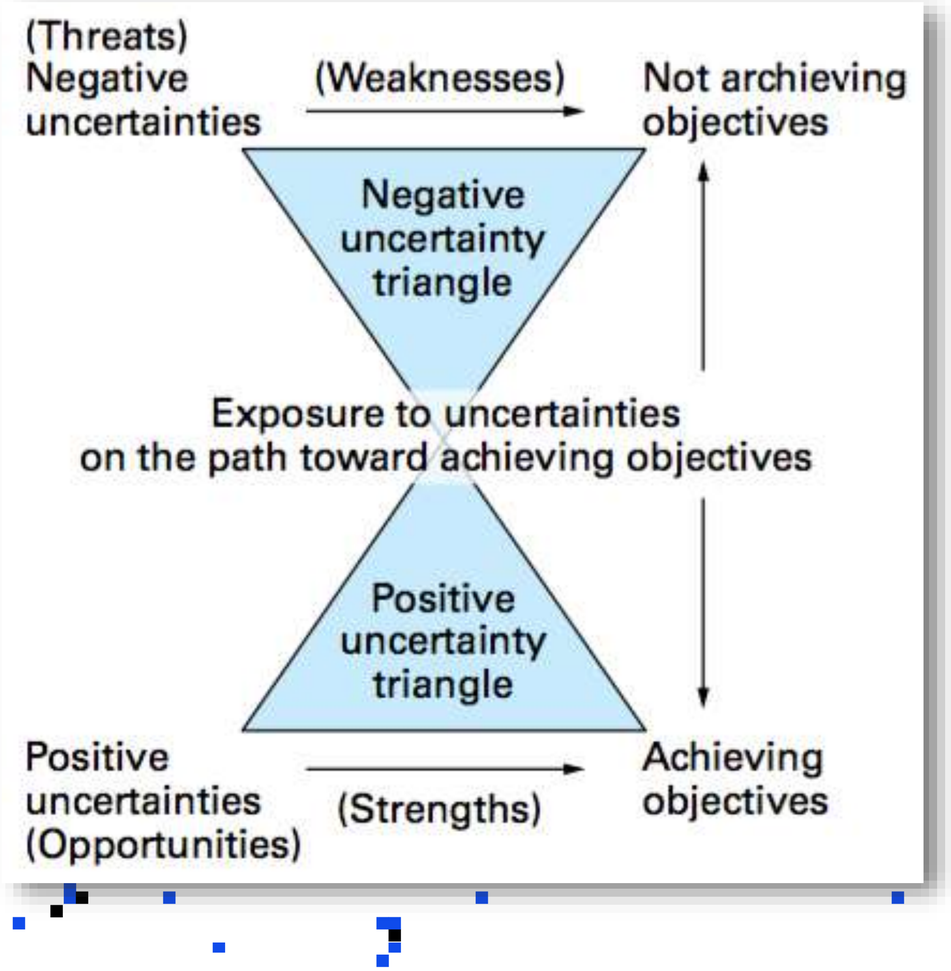
Mathematics and Risk Management Analogy

- Risk management can actually be compared with mathematics.
- Both disciplines are commonly regarded as “auxiliary science” domains, helping other “true sciences” to get everything right.
- Mathematics is needed for correct laws in physics, chemistry, etc., and risk management is required for optimized applications in physics, chemistry.



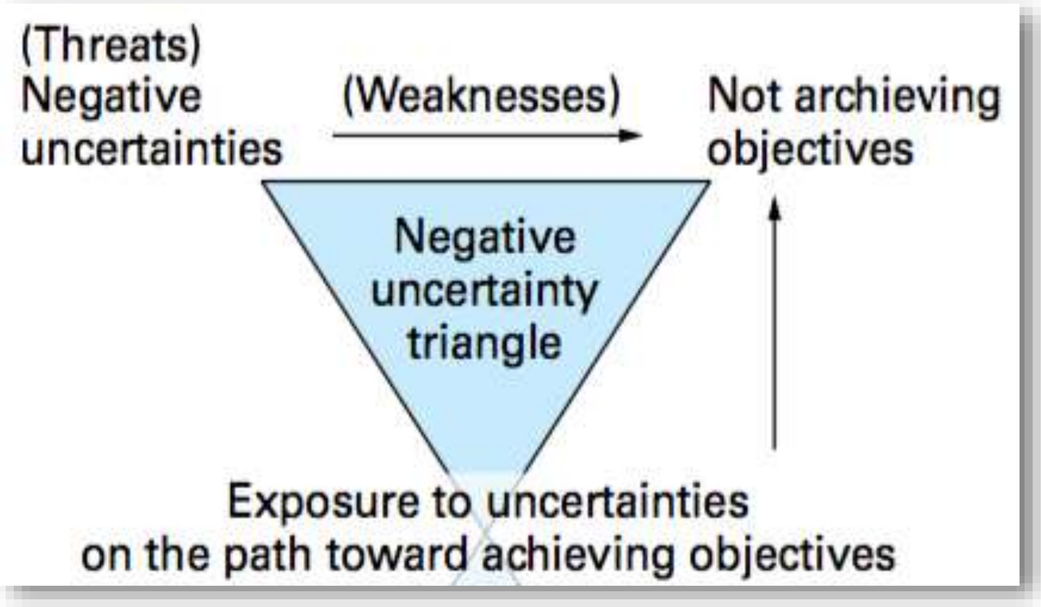
Risks and Uncertainties Complexity

- Risk means different things to different people at different times.
- As mentioned, one element characterizing risk is the notion of uncertainty.
- This figure displays the uncertainty sandglass, with SWOT elements situated within the concept.



The Focus of 49006

- The focus is on upper triangle, hazards, exposure to hazards, and losses.
- If one of these elements is removed from this triangle, there is no risk.
- The engineering aspects of risk management in this subject focus on how to diminish, decrease or soften as much as possible one of the three elements or a combination thereof.

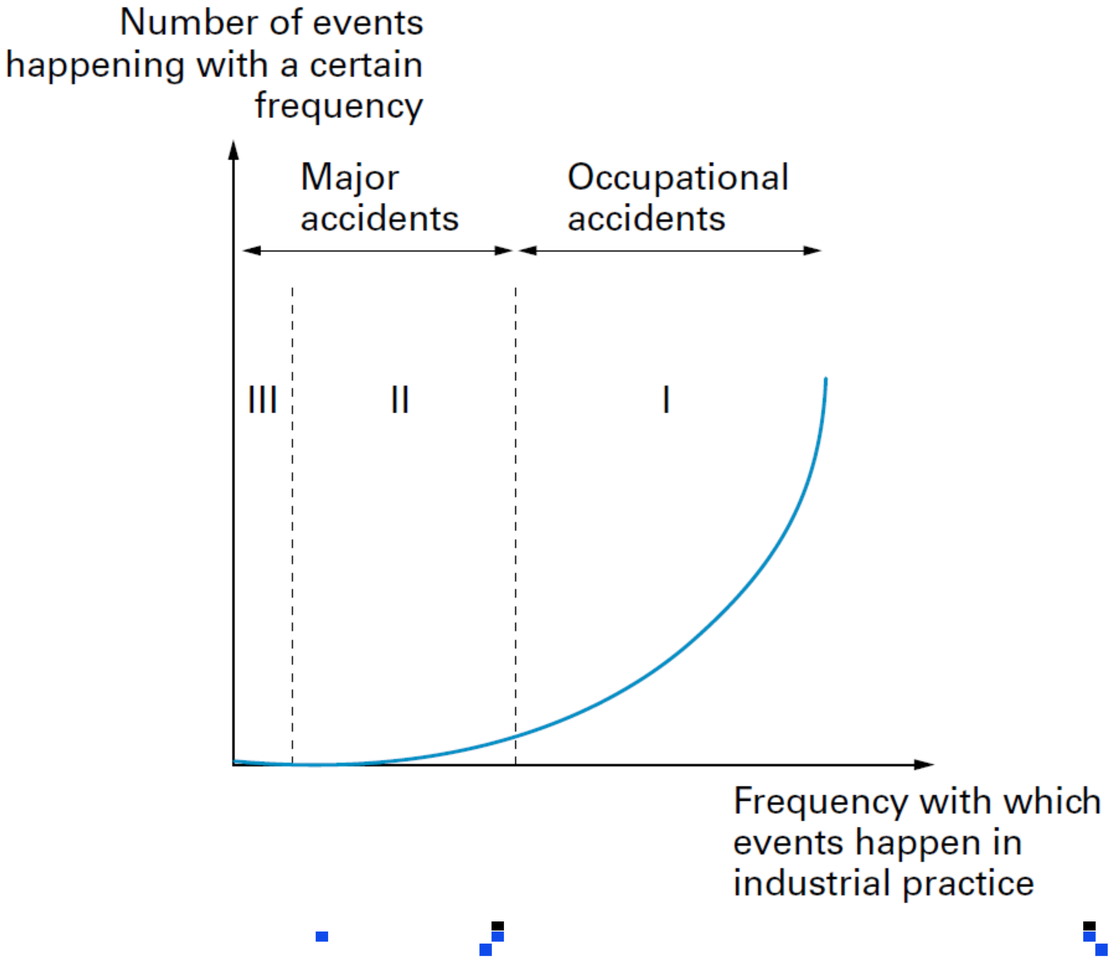


Risks and Uncertainties Complexity

- There are three types of uncertainties can be identified:
  - Type I uncertainties where a lot of historical data is available (from negative risk viewpoint, affect individual employees, e.g. work-related accidents).
  - Type II uncertainties where little or very little historical data is available (affect a company, e.g. large explosions, internal domino effects).
  - Type III uncertainties where no historical data is available (unprecedented and unseen disasters, e.g. Seveso (Italy, 1976), Bhopal (India, 1984), 9/11 Terrorist Attacks (USA, 2001), Fukushima (Japan, 2011)).

Risks and Uncertainties Complexity

- This figure illustrates in a qualitative way the three uncertainty types of events as a function of their frequency.
- Type I unwanted events can be regarded as “occupational accidents” (e.g. accidents resulting in the inability to work for several days, accidents requiring first aid, etc.).
- Type II and Type III accidents can both be categorized as “major accidents” (e.g. multiple fatality accidents, accidents with huge economic losses, etc.).



Black Swan (Type III events)

- “Black swan” is used to describe anything “impossible or not existing”.
- Three main features of black swan events could be identified:
  - The event has extreme or major impact.
  - The event is unexpected or not probable.
  - After the occurrence of the event, explanations are formulated making it predictable or expectable.

https://www.youtube.com/watch?v=BDbuJtAiABA

Basic Concepts

Hazards and Risks

- Hazard is defined as “The potential of a human, machine, equipment, process, material, or physical factor to lead to an unwanted event possibly causing harm to people, environment, assets or production”.
- (Negative) Risk is the possibility of loss (fatality, injury, damage, detriment, etc.) created by exposure to one or more hazards, and can be calculated as:

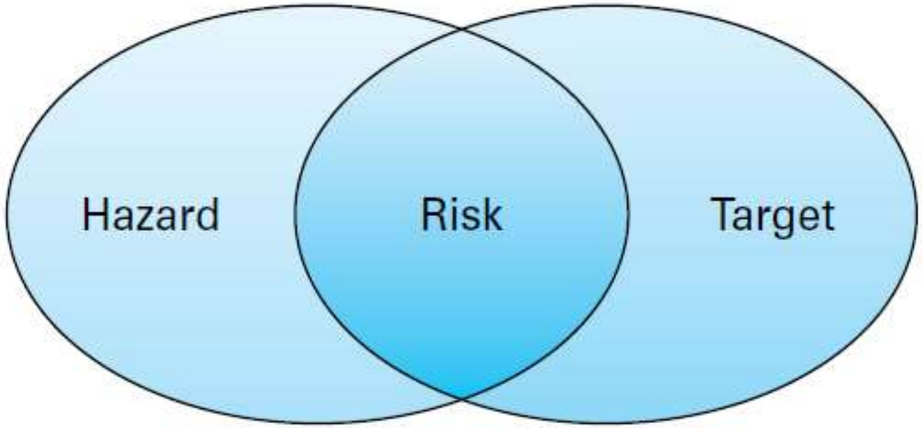
Risk = (Likelihood or frequency of unwanted event) × (Severity of unwanted event consequences)

Examples

Example	Hazard	Exposure	Loss	Risk
Fryer in use	Heat	Person working with the fryer	Burns	Probability of children having burns of a certain degree
Toxic product	Toxicity	Person working with the toxic product	Intoxication	Probability of worker being intoxicated with a certain severity
Storage of products that look alike	Looking alike	Order by client of one of the look-alike products	Wrong delivery to client	€10,000 claim by client over a certain period of time

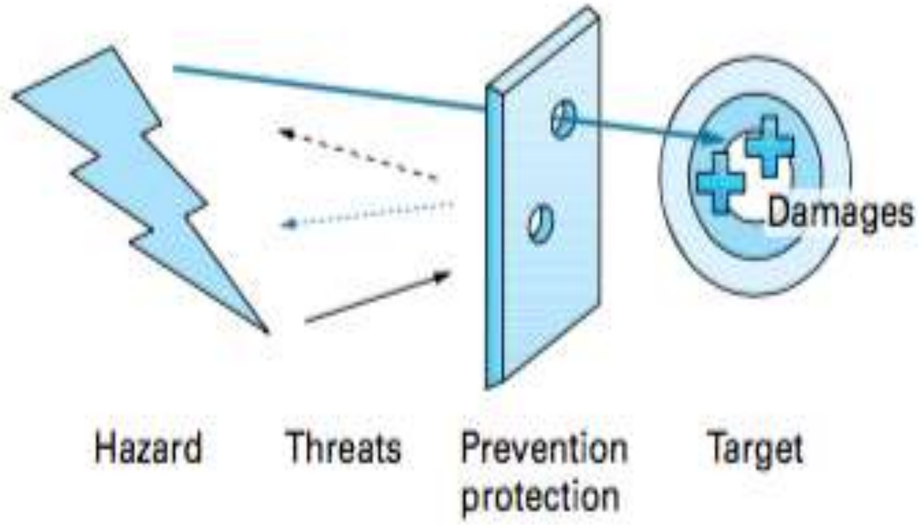
Physical Description of Risk

- Risk is found at the interface, or at the cross section, of a hazard and a target.



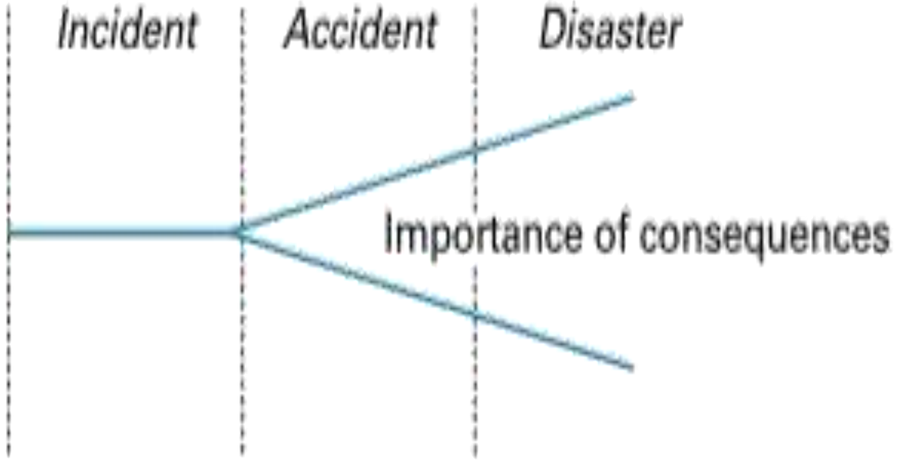
Physical Description of Risk

- A threat is the potential of a hazard to cause damage.
- Risk is physically characterized by four elements:
  - A hazard.
  - One or many targets threatened by the hazard.
  - The evaluation of the threat.
  - The measures taken to reduce the threat.



Physical Description of Risk

- The main difference between an incident and an accident is generally defined by the importance of caused or sustained damage.
- The notions of accident is defined as follows:
  - Incident: An event that leads or could have led to an accident.
  - Near-accident or near-miss: An incident that does not damage health or leads to any deterioration or losses.
  - Accident: An unexpected event that leads to health deterioration, lesions, damages or other losses.
  - Disaster: A major accident that is brutal and sudden and of an enormous dimension.



Simplified Interpretation of Risk

- Risk cannot be felt by human senses; it can be only measured or estimated.
- The simplest model defines that the probability of a certain risk depends on:
  - The frequency by which the target is exposed to the hazard (sometimes called likelihood of occurrence), supposing that the hazard threatens the target.
  - The evaluation of its consequence corresponding to a measurement of the severity of the mentioned consequences.

$$\text{Risk} = \text{frequency} \times \text{severity}$$

$$R = F \cdot G$$

Risk Calculation

- A simple mathematical representation of risk (expected loss) is the form commonly found in the literature as:

$$Risk\left(\frac{Consequence}{Unit\ of\ time\ or\ space}\right) = Frequency\left(\frac{Event}{Unit\ of\ time\ or\ space}\right) * Severity\left(\frac{Consequence}{Event}\right)$$

- Example: Annual fatality risk due to automobile accidents in US:

$$15 * 10^6\left(\frac{accidents}{year}\right) * 1\left(\frac{fatality}{300\ accidents}\right) = 50{,}000\ \left(\frac{fatalities}{year}\right)$$

Risk Calculation

- Such an equation of risk is very convenient for many purposes, but it also creates several difficulties:
  - Determining the units in which risk is measured: Risk can be expressed in terms of number of fatalities, the monetary losses per unit of time, the probability of certain injuries to people, the probability of a certain level of damage to the environment, etc.
  - In some cases, especially in Type II and III events, it is obviously very difficult to estimate the likelihood of a given unwanted event and the magnitude of its consequences.

Simplified Interpretation of Risk

- To be consistent with the concept that measures have been taken against a threat, the notions of protection and prevention are taken into account in the following formula:

$$R = F \cdot G = \left(\frac{N \cdot T}{Pre}\right) \cdot \left(\frac{D}{Pro}\right)$$

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

Severity *G* is function of:
D – “crude” hazard of the situation
Pro – level of protection implemented in the light of this hazard

Simplified Interpretation of Risk

$$R = F \cdot G = \left(\frac{N \cdot T}{Pre}\right) \cdot \left(\frac{D}{Pro}\right)$$

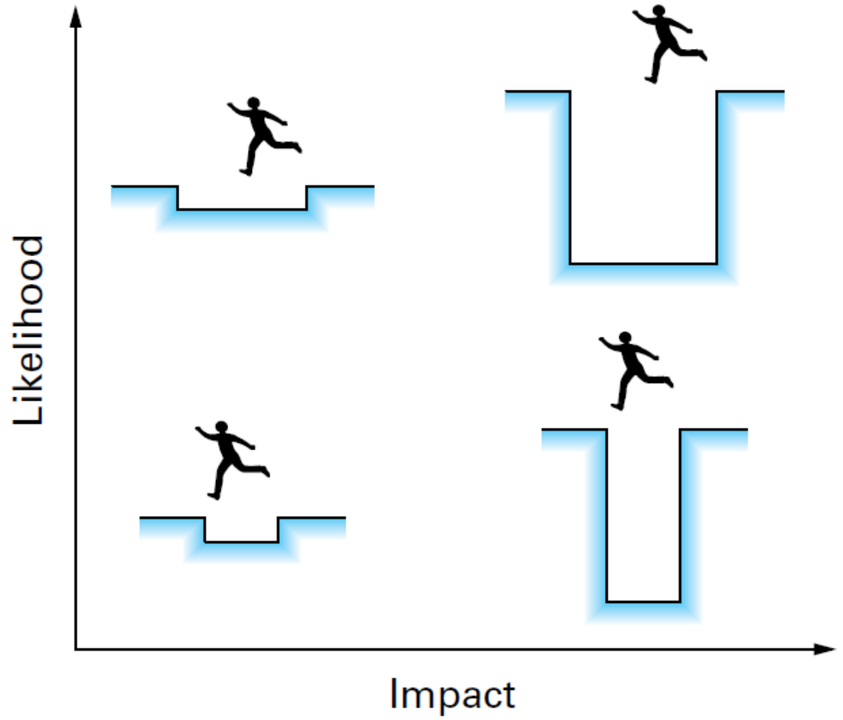
- This formula indicates the possible pathways and solutions to reducing the risk which acts act on:
  - Severity → reduce the hazard, increase protection measures
  - Frequency → reduce the exposure time, reduce the number of exposed targets, increase prevention measures

Simplified Interpretation of Risk

- Changing the risk by reducing the occurrence of its components and/or their severity means addressing 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*)?

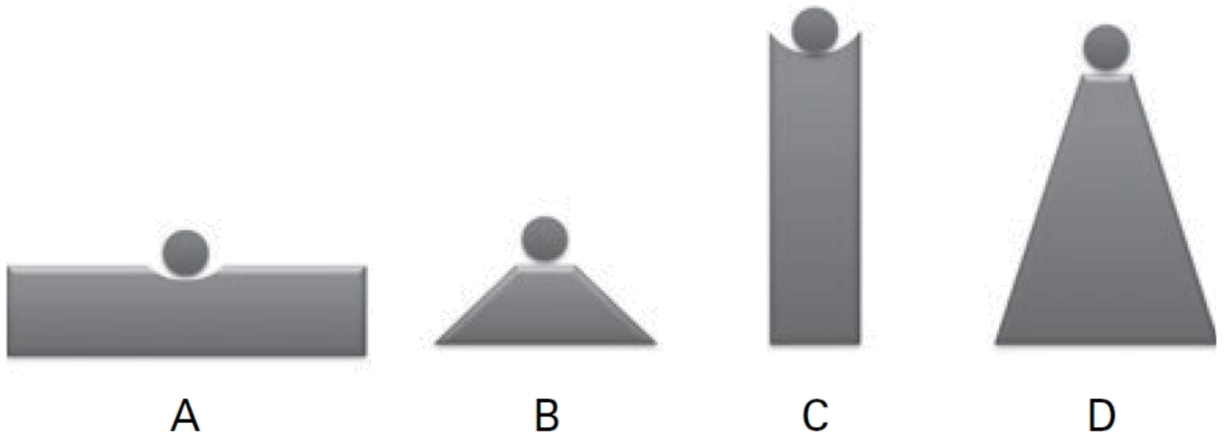
Simplified Interpretation of Risk

- The evaluation of risk can be presented in a matrix:



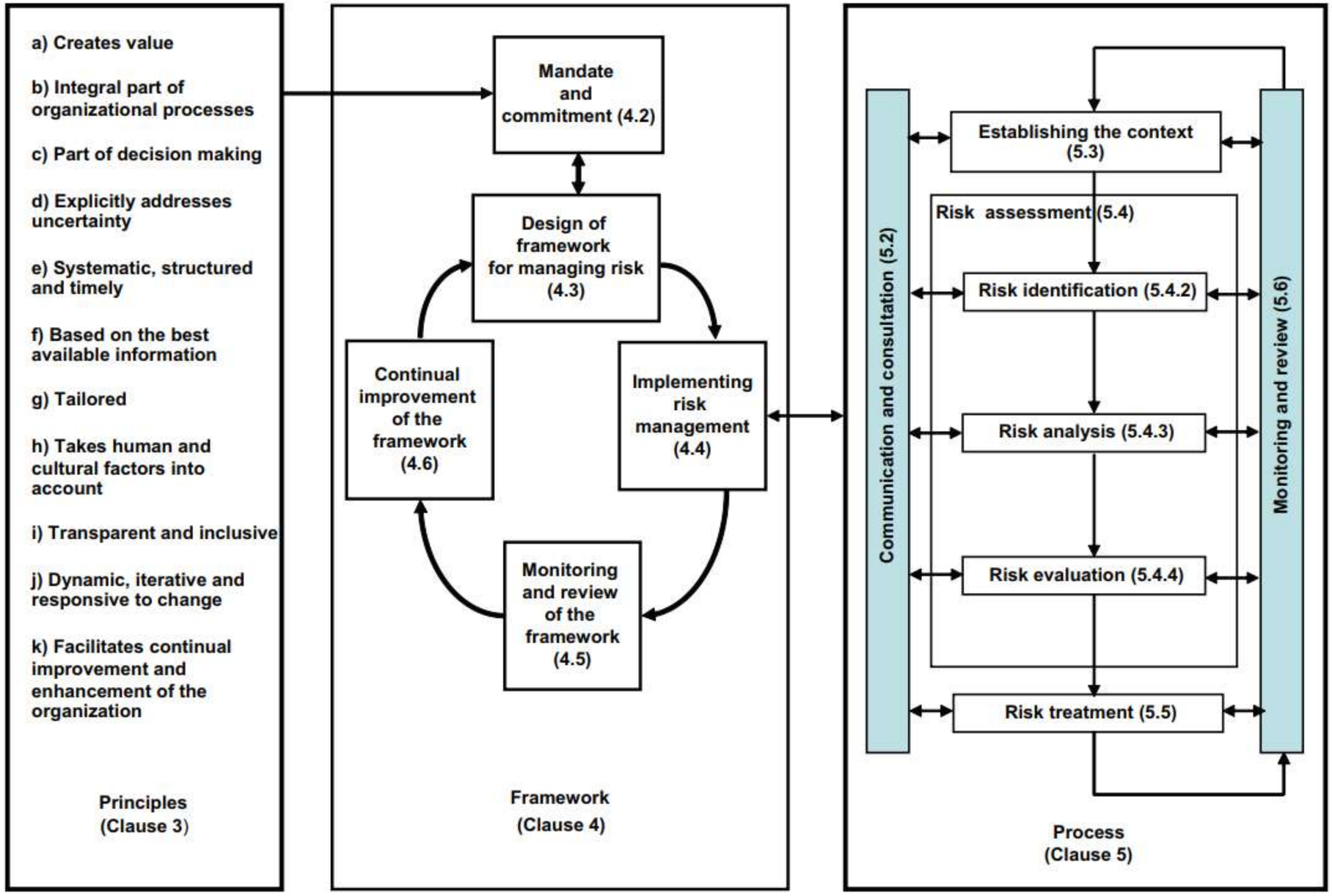
Simplified Interpretation of Risk

- The quantification of risk does not easily indicate something about occurrence and severity. The illustration can help to understand different classes of risk:
  - A – low probability, low damage = low risk
  - B – high probability, low damage = medium risk
  - C – low probability, high damage = medium risk
  - D – high probability, high damage = high risk



Engineering Risk Management (ERM)

ERM – AS/NZS ISO 31000:2009



ERM – AS/NZS ISO 31000:2009

- For risk management to be effective, an organization should at all levels comply with the principles of AS/NZS ISO 31000:
  - RM creates and protects value.
  - RM is an integral part of all organizational processes (not a stand-alone activity).
  - RM is part of decision-making.
  - RM explicitly addresses uncertainty.
  - RM is systematic, structured and timely.
  - RM is based on the best available information.

ERM – AS/NZS ISO 31000:2009

- AS/NZS ISO 31000 principles (continued):
  - RM is tailored and is aligned with the organization’s external and internal context and risk profile.
  - RM takes human and cultural factors into account.
  - RM is transparent and inclusive.
  - RM is dynamic, iterative and responsive to change (RM continually senses and responds to change).
  - RM facilitates continual improvement of the organization.

Objectives and Importance of ERM

- The objectives of ERM are defined as: “the early and continuous identification, assessment, and resolution of non-financial risks such that the most effective and efficient decisions can be taken to manage these risks”.
- ERM offers an answer to the ever more difficult task of managing the risks of organizational systems, technology, infrastructure, etc.
- Early and continuous risk identification, risk-informed (risk-based) decision-making, gaining a systemic overview of an organization, proactive planning for unwanted events, proactive learning and learning from incidents, intelligent resource allocation, situational awareness and risk trends, etc.

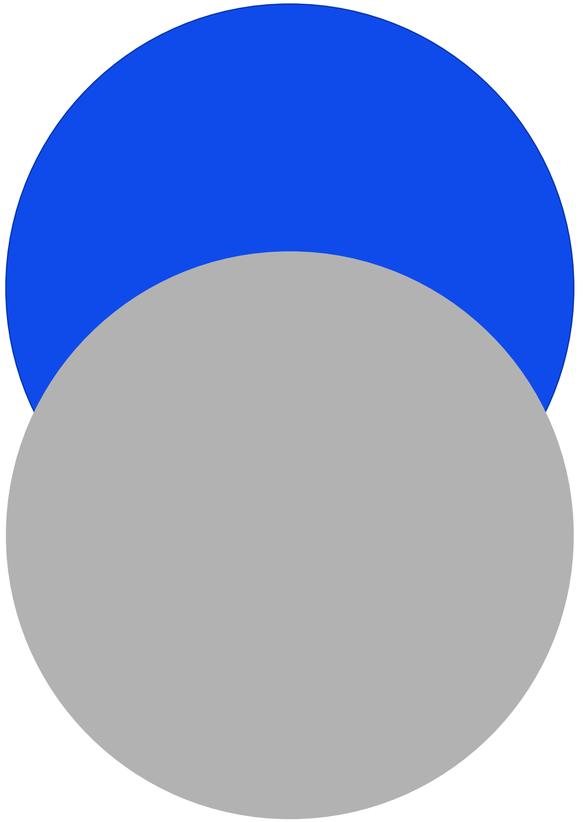
Objectives and Importance of ERM

- Well-known management disciplines of ERM:
  - Operation management (*ERM of operations*)
  - Change management (*ERM of changes*)
  - Project management (*ERM of projects*)
  - Crisis management (*ERM of crises*)
  - Innovation management (*ERM of innovations*)
  - etc

How Much Risk Management

Summary

- The only certain thing about future is that everything is uncertain.
- Risks need three factors: hazards, losses and exposure.
- Decreasing (or even avoiding or taking away) one of these parameters, or (one of) the characteristics of these parameters, in one way or another, leads to lower risks (or even to no risk).
- AS/NZS ISO 31000:2009 provides the risk management process, principles, and values.



Thank you!