



Risk analysis in a complex globalised world

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Outline

- Risk(s)
- Risk analysis and management
- Risk challenges in a complex world
- Risk analysis, Extreme events and Decision Theory program
- Discussion



Risk

- Being alive means seeking opportunities and taking risks
- There is uncertainty about the outcome and the possibility that the outcome might be undesirable
- Possible definition
 - A condition in which there is a possibility of an adverse deviation from a desired outcome that is expected or hoped for.
 1. (List of potential events)
 2. The probability that an adverse event occurs
 3. The consequences of the adverse event

Measuring risk??



Risks

- Many types of risk: environmental, financial, political, technological,...
- Standard classifications:
 - Financial and nonfinancial risks (loss is financial or not)
 - Financial: credit, operational, market, integrated,...
 - Static or dynamic risks
 - Dynamic (changes in economy), Static (Nature, dishonesty of others,...)
 - Fundamental and particular risks
 - Group: Unemployment, war,... vs Individual: House burnt,...
 - Pure (loss or no loss) and speculative (loss or win) risks
 - Pure: Personal, property, liability,...



The burden of risk

- Some losses will actually occur: Avoid or alleviate impact
- The uncertainty is a burden: insure, reserve fund (with entailed opportunity cost)
- Deterrent on economic growth, impact on cost of capital
- Feeling of frustration and mental unrest (though there are risk seekers)
- A growing number and variety of risks
 - From nature and predators, to risks associated with nuclear energy, air transportation, information technology, terrorism, climate change,...
- With increasing severity of losses
 - Each catastrophe seems to exceed previous losses... More wealth, more investment, more assets exposed to loss



Risk aversion and risk proneness

- Do you prefer:
 - A: 1000€ with probability $\frac{1}{2}$ and 0€ with probability $\frac{1}{2}$
 - B: 500€ for sure

- If A, risk prone. Convex utility function
- If B, risk averse. Concave utility function
- If indifferent, risk neutral. Linear utility function



Risk: Extreme events

- Model events that (almost) never occur
- If it occurs, the underlying systems and organizations are often changed so that the event cannot occur in the same way again
- Probability models for extreme events
- The use of expert opinion



Risk analysis

A systematic analytical process for assessing, managing and communicating the risk performed to understand the nature of unwanted, negative consequences to human life, health, property or the environment (so as to reduce and eliminate it)

1. Risk assessment. Information on the extent and characteristics of the risk attributed to a hazard.
2. Risk management. The activities undertaken to control the hazard
3. Risk communication. Exchange of info and opinion concerning risk and risk-related factors among risk assessors, risk managers and other interested parties.



Risk analysis: What for??

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Risk management for an existing or proposed facility

Development of regulations

Demonstration of compliance with regulations

Demonstration of need for further improvement

Litigation

Scientific enquiry



Risk analysis and management: A brief history

- Initially predated by insurance
- The impact of decision sciences
- Systems safety (military and aerospace engineering)
- Management: Having identified and evaluated the risks to which it is exposed, can plan to avoid the occurrence of certain losses and minimize the impact of others. The cost of risk can be managed and held to the lowest possible levels.



Risk analysis and management: Some milestones

Selected from McDaniels

- 1926. Muller discovers that X-rays induce genetic mutations in fruit flies 1500 times more quickly than normal
- 1939. UK establishes 99.999% reliability for 1 hour flying time of commercial aircraft
- 1949. Callendar speculatively links 10% increase of CO₂ between 1850-1940 with observed warming in Europe and North America started in 1880
- 1961 Fault tree methods developed at Bell Labs for USAF to evaluate Minuteman launch safety
- 1972-1973 Kahnemann and Tversky's Subjective Probability and Psychology of Prediction papers
- 1975 US Nuke Regulatory commission publishes first probabilistic risk assessment for reactor safety
- 1981 Kaplan and Garrick characterize risk in terms of outcome scenarios, consequences and their probability of occurrence
- 1999 Haimes outlines role of risk analyses to address emerging threats to critical infrastructures, including cyber sabotage and terrorism



Risk management tools

Design and implement procedures to minimize occurrence of loss or their impact

- Risk control (Minimize risks, at the least possible cost)
 - Risk avoidance. Decisions made to prevent a risk from existence: Do not produce this because of its inherent dangers
 - Risk reduction. Decisions to reduce the likelihood (loss prevention) or the severity of losses (loss control). Warnings. Deployment of physical or human resources...
- Risk financing (Arrangements to guarantee availability of funds to meet eventual losses)
 - Risk retention. Intentional or unintentional (perhaps with a fund)
 - Risk transfer. Insurance



The risk management process

1. Determination of objectives
2. Identification of risks
3. Evaluation of risks
4. Considering alternatives and selecting the risk treatment device
5. Implementing the decision
6. Evaluation and review



Risks in modern world

Risk management is the top priority for top management in major companies. Three years ago: human resources and talent management (Accenture report)

Demands for security in an increasingly globalised economy, pressure of regulators,



Risks in modern world

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Risk priorities for CIOs:

- Loss of business critical information
 - Critical systems failure leading to operational inactivity
 - Ilicit use of confidential information
 - Fulfilling regulations (Basel II, SOX,...)
-
- In a context of increase of software and hardware (interconnected) complexity



Risk: challenges in a complex world

- Katrina, Tsunami,...
- S-11, M-11,...

- Low probability, high consequence events more likely than ever??



Risk: challenges in a complex world

- Population has increased substantially: facilities previously remote, now close to lots of population
- Use of toxic or potentially toxic materials increased, genetically modified organisms
- Public much more aware of hazards posed to humans, climate change
- Need to protect critical infrastructures to assure continuity of a nation. Interconnected international infrastructures
- Government agencies tend to involve the public, multiplicity of stakeholders
- Awareness about equity with respect to risks
- Increasing interdependencies within the world
 - Interdependent security systems: Each firm is part of an interconnected system and must decide independently whether or not to adopt protective strategies. They may suffer if others do not adopt similar measures



Interdependencies. Adversarial risk analysis

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	Company B invests in baggage security	Company B does not invest in baggage security
Company A invests in baggage security	Both incur security costs Low security risks	A incurs security costs Relatively high security risk
Company A does not invest in baggage security	B incurs security costs Relatively high security risk	Equilibrium:A,B avoid costs High security risk



Risk: Finance

- Highly mathematical
- Global Association of Risk Professionals
- VAR (Value at Risk) interpreted as cutoff point such that a loss will not happen with probability greater than (a given) p (e.g. 0.95)
- Basel I and Basel II Accords



Risk: Project management

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- Standard practice 1

Increase costs by a default 25%

- Standard practice 2

For each incurred cost: provide minimum, most likely, maximum. Fit triangular distributions. Simulate.



Risk: Environment

- Problem statement
 - Question to be answered
- System description
 - Physical processes in the system, time scales of interest,...
- Risk calculation
 - Release assessment
 - Identification of contaminants and quantitative estimation of release probabilities and release rates in environment
 - Transport assessment
 - Identification of pathways for contaminants, estimation of contaminant concentration in air, water, soil and food at specific locations in time and space
 - Exposure assessment
 - Identification of exposed populations and exposure routes and estimation of the rate at which humans are exposed to the contaminant
 - Consequence assessment
 - Identification of types of health effects caused by a contaminant and a quantitative estimate of the probability and/or severity of those effects
- Integration and iteration
 - Integrate parts (eg water and air releases,..)
- Dose-response modelling (animal to human extrapolation, high to low extrapolation,...)



Risk: Many unformalised criteria

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- VAR
- ALARP As low as reasonably practicable
- ALARA As low as reasonably achievable
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Risk analysis, Extreme Events and Decision Theory Programme

Address fundamental issues in risk analysis and the linked problems associated with extreme events and decision theory

Integration of expertise developed by researchers in different scientific communities (insurance, finance, ICT, environmental engineering,...)



Risk analysis: Challenges

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■ Cost prediction

To a large extent, costs are not treated as random in risk analyses and are estimated without attention to associated uncertainties

■ Elicitation of expert opinion

The data underlying many risk analyses constitute expert opinions rather than conventional measurements. Despite ongoing attention to eliciting and incorporating expert opinion, there do not seem to be effective, available tools.

■ Risk perception

Increasing divergence between risk perception and risk reality (Based on number of deaths, in most years is more dangerous to drive to the airport than to fly). Tools to communicate and visualize risk!!!

■ Extreme values

Theory of multidimensional extremes. Multiple consequences of rare events.

■ Adversarial risks

Formalising analysis of risks from intelligent opponents, possible willingness to cooperate, transfer of risks,



Challenge. Adversarial risk analysis

- Until now game theory viewed by risk analysts of little relevance for practical risk management decision making
- Increased interest in terrorism, homeland security, critical infrastructure protection (attacker-defender)
- Increased interest in risk-informed regulation (regulator-regulated firm)
- Interdependent security settings (each individual or firm that is part of an interconnected system must decide independently whether or not to adopt protective strategies)



Challenges: Stakeholder involvement

- Public involvement in risk analysis is increasing
 - Producing better decisions and outcomes
 - Changing the manner in which decisions are made or deliberations are conducted
 - Better information, better communication, increased confidence in institutions,...

- More costs, Delayed processes
 - Deliberative polls
 - Referenda
 - Workshops
 - Negotiated rule making
 - ...



Challenges: Risk communication

- Many barriers to effective risk communication
 - Many factors influence risk perception and affect risk acceptance (Do skydiving but oppose nuclear power; risk of death is about an order of magnitude less than that of automobile travel, but this is better accepted)
 - Voluntary vs Imposed
 - Under my control vs Under another's control
 - Technical information
 - Hazards, negative feelings.
 - People tend to overweight small probabilities in decision making



Risk analysis and management framework (Single DM)

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- Forecast costs under normal circumstances
- Identify events, estimate probabilities and impacts on costs (additional induced costs)
- Forecast costs (a mixture model). Compute expected utility
- Identify interventions, estimate impact on probabilities and/or costs.
- Compute expected utilities. Choose best



Risk analysis and management framework (several DMs)

- Forecast costs and model preferences for me
 - Forecast costs under normal circumstances
 - It. under abnormal circumstances
 - Model preferences
- Forecast costs and model preferences for others
- Repeatedly solve problem (Bayes-Nash equilibrium)
- Summarise solutions

- What if they cooperate? Risk transfer?
- What if other than costs?



Discussion

- Risk analysis has an important, though fragmented and not always well founded, tradition
- Modern times brings in new challenges
 - Dealing with intelligent rivals
 - Participatory processes
 - Risk communication (education)