

From Risk Analysis to Adversarial Risk Analysis

Part 0. Intro

David Ríos, david.rios@icmat.es

AXA-ICMAT Chair in ARA and Royal Academy of Sciences

Goals

- Provide a review of key concepts and issues to support decision makers in risk management
- Both individuals and groups
- Individuals. Emphasis on decision analytic perspective. Risk analysis
- Groups. Emphasis on game theoretic perspective . Adversarial risk analysis
- Emphasis on risk analysis applications. Safety and Security
- Introduce and discuss some open problems

Outline

- Introduction
- Bayesian Decision Analysis
- Framework for risk analysis.
 - Aviation Safety
- Games
- Framework for adversarial risk analysis.
 - Security
- Some open problems

Approaches to decision making

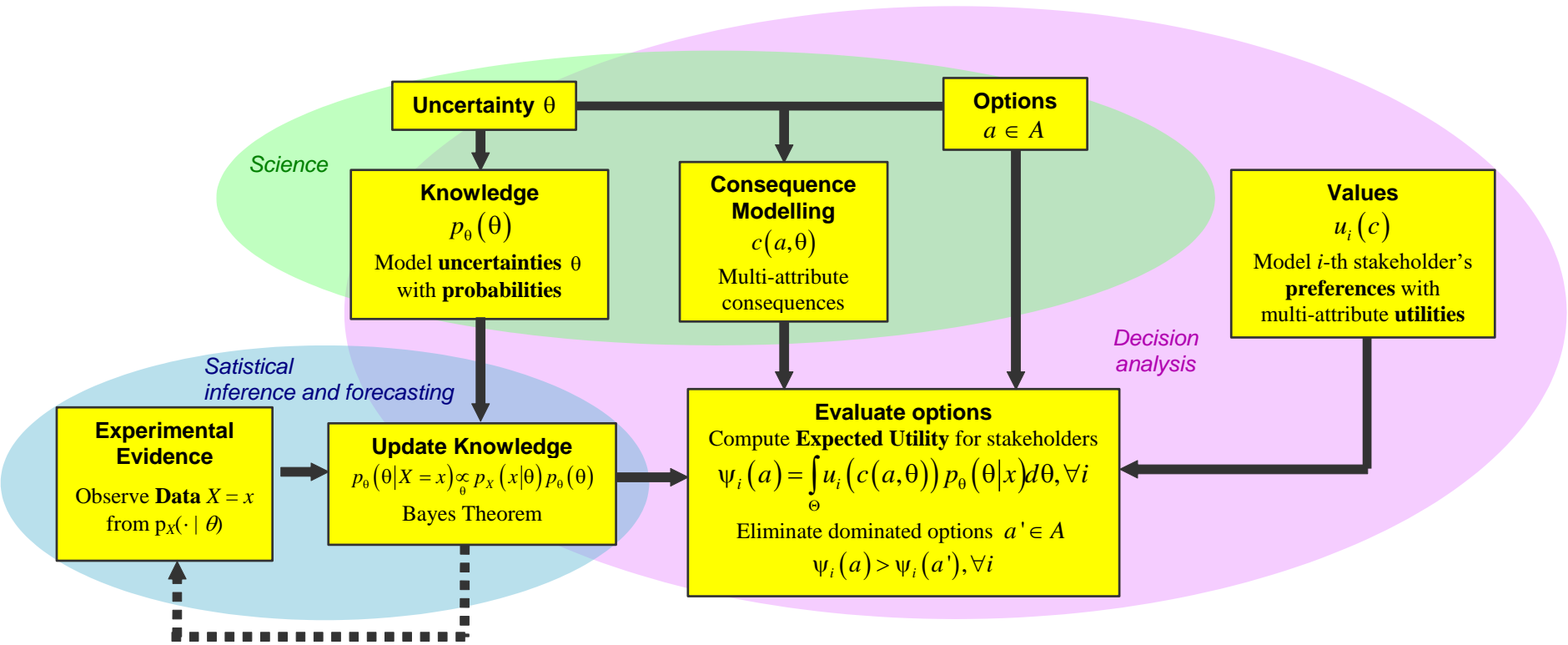
- Descriptive
 - Understanding of how decisions are made
- Normative
 - Models of how decision should be made
- Prescriptive
 - Helping DM make smart decisions
 - Use of normative theory to support DM
 - Elicit inputs of normative models
 - DM preferences and beliefs (psycho-analysis)
 - use of experts
 - Role of descriptive theories of DM behavior

Normative models of decision making under uncertainty

- Models for a single DM
 - vN-M expected utility
 - Objective probability distributions
 - Subjective expected utility (SEU)
 - Subjective probability distributions
- Example: investment decision problem
 - One **decision** variable with two alternatives
 - Where to invest?
 - Treasury bonds
 - IBM shares
 - One **uncertainty** with two possible states
 - IBM share price at the end of the year
 - High
 - Low
 - One evaluation criteria for **consequences**
 - Profit from investment
- The simplest decision problem under uncertainty

Subjective expected utility solution

- If DM's decision behavior consistent with some set of "rational" desiderata (axioms) DM decides as if he has
 - **probabilities** to represent his **beliefs** about the future price of IBM share
 - "**utilities**" to represent his **preferences** and **risk attitude** towards moneyand choose the alternative of maximum expected utility
- The subjective expected utility model balance in a "rational" manner
 - the DM's beliefs and risk attitudes
- Application requires to
 - know the DM's beliefs and "utilities"
 - Different elicitation methods
 - compute of expected utilities of each decision strategy
 - It may require approximation in non-simple problems



Game theory arena

- Non-cooperative games
 - More than one intelligent player
 - Individual action spaces
 - Interdependent consequences
- Cooperative game theory
 - Normative bargaining models
 - Joint decision making
 - Binding agreements on what to play
 - Given players preferences and solution space
 - Find a fair, jointly satisfying and Pareto optimal agreement/solution
 - Group decision making on a common action space (Social choice)
 - Preference aggregation
 - Voting rules
 - Arrow's theorem
 - Coalition games

Applications: Risk Analysis

- The elusive concept of risk
- Risks
- Risk analysis and management: challenges in a complex world

The elusive concept of risk

Risk related concepts abound in various fields

- **Statistical Decision Theory:**

Risk function

Bayes risk

- **Statistics**

Extreme event modelling

Reliability

- **(Econ) Decision Theory:**

Decision making under risk vs under uncertainty

- **Finance**

Value at Risk (and related concepts)

- **Insurance**

Annual Expected Loss

-

The elusive concept of risk

- Being alive means seeking opportunities and taking risks.
Taking smart risks (The Art of Living Dangerously)
- 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

Risks

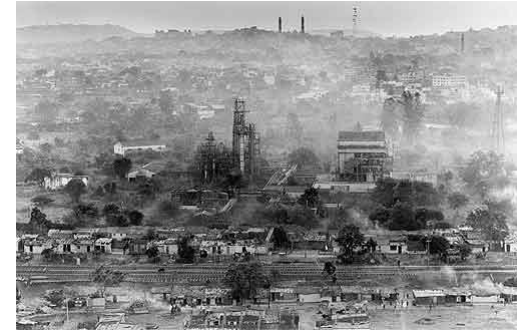
- Many types of risks: environmental, financial, political, technological,...
- Standard classifications:
 - Financial and nonfinancial risks
 - Financial: credit, operational, market,...
 - Static or dynamic risks
 - Associated with normal functioning (even if there are no changes) (nature, dishonesty,...) (loss),
 - Associated with changes (win or loss)
 - Fundamental and particular risks
 - Group (Earthquake) vs Individual (Burnt home)
 - Pure (loss, no loss) and speculative (win, loss) risks
 - Pure: Personal, property, liability,...

Risks: Their burden

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

Bhopal

- December 3rd 1984
- Escape of 42 ton of met-isoc
- 20000 dead
- 600000 affected
- Plant abandoned, U.Carbide did not respond
- 2010. 8 managers condemned to two years and 8900 euros fine



Aznalcóllar

- April 25th 1998
- Heavy metal reservoir from Boliden broke
- Very high environmental impact
- 2004. Condemn to Boliden 45 M euros.
Boliden announces will not pay because of
an external agent origin
-



S-11

- September 11th 2001
- Suicidal terrorist attacks in US
- 3000 dead, numerous infrastructure damaged
- ...



Safety vs Security

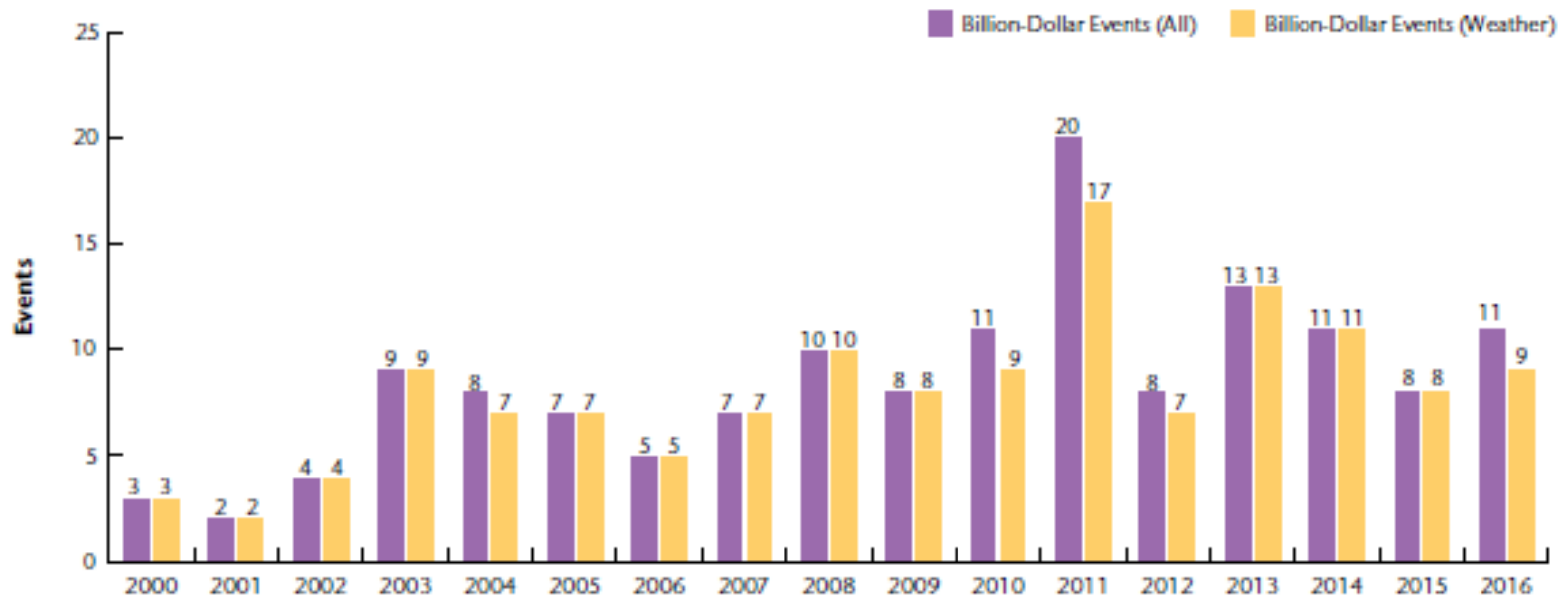


Risk: challenges in a complex world

- Sao Paulo airport accident
Population has increased: facilities previously remote, now close to lots of population
 - Chinese toys
Use of toxic or potentially toxic materials increased, genetically modified organisms
 - Climate change
Public much more aware of hazards posed to humans
 - Estonian hacker attack
Need to protect critical infrastructures to assure continuity of a nation. Interconnected international infrastructures. Cold cyberwar
 - EU Water directives
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
 - Katrina, Tsunami, Haiti,
The 'usual' great natural disasters (even greater??)
 - 11-S, 11-M, Somalian pirates, ...
Global terrorist and delictive organisations run as corporations (cutthroat capitalism)
- Low probability, high consequence events more likely than ever

Evolution of Catastrophe Insured Losses

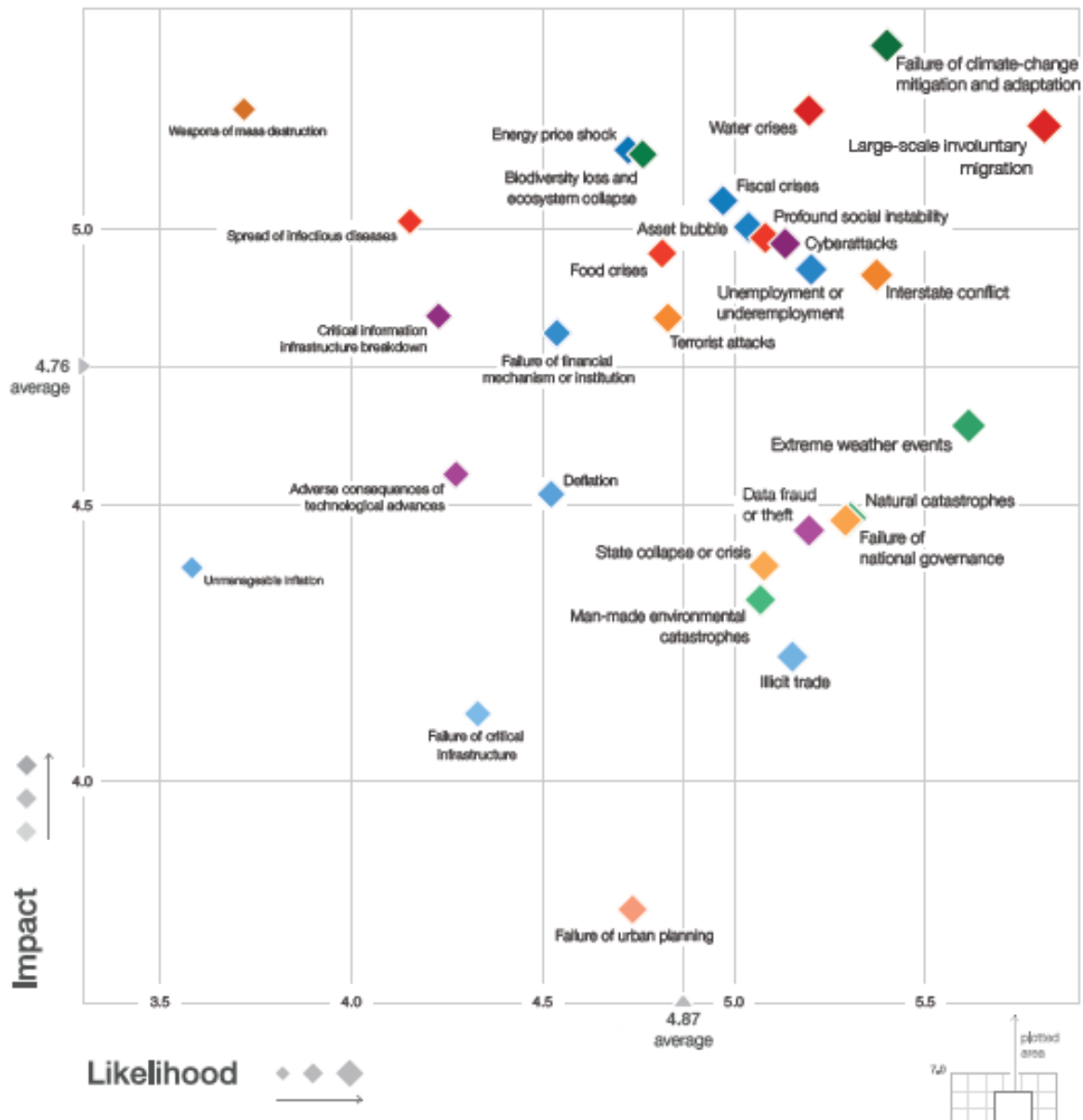
Exhibit 8: Global Billion-Dollar Insured Loss Events



Risks in modern world

Risk management top priority for top management in major companies. A few years ago: human resources and talent management

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



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.

1 bis. Concern assessment

Risk analysis: What for??

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

Which is the best security resource allocation in a city?

City as a map with cells

Each cell has a value

For each cell, a predictive model of delictive acts

Allocate security resources (constraints)

For each cell predict the impact of resource allocation

Optimal resource allocation

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Allocate security resources (constraints)

For each cell predict the impact of resource allocation

Optimal resource allocation

NB: The bad guys also operate intelligent and organisedly!!!

Which is the best HW/SW maintenance for the university ERP?

Model HW/SW system (interacting HW and SW blocks)

Forecast block reliability

Forecast system reliability

Design maintenance policies

Forecast impact on reliability (and costs)

Optimal maintenance policy

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Optimal maintenance policy

NB: Again, what happens with the bad guys attacking our system?

Risk analysis: A brief history

- Predated by insurance
- The impact of decision sciences
- Systems safety (military, aerospace engineering, nuclear industry)
- 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.
- The presence of intelligent adversaries: risk analysis+game theory

Risk management tools

- Design and implement procedures to minimize occurrence of loss or their impact
- Risk control (Minimize, at the least possible cost, risks)
 - 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

Preserve the operating effectiveness of the organisation

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