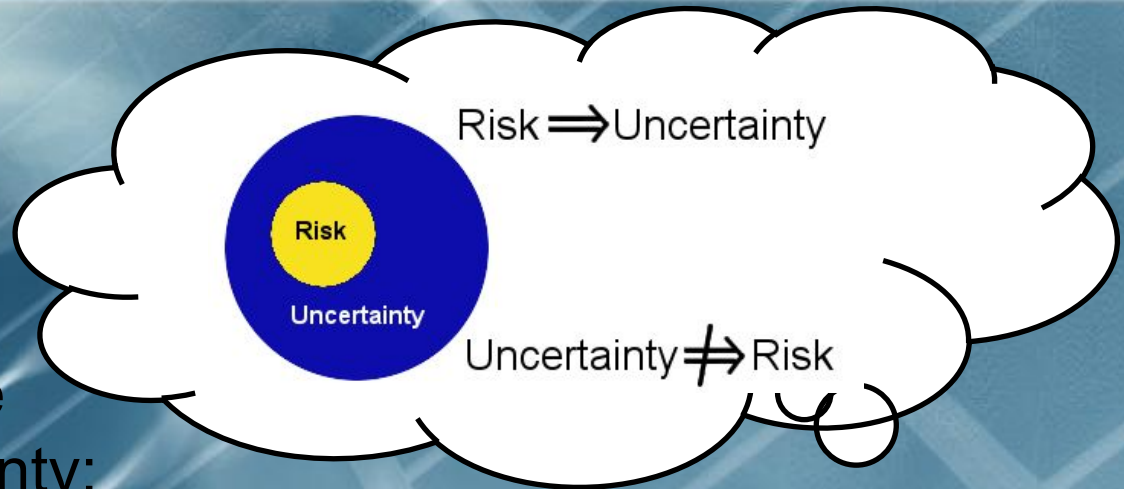




A SHORT INTRODUCTION TO THEORY OF RISK

RISK & UNCERTAINTY

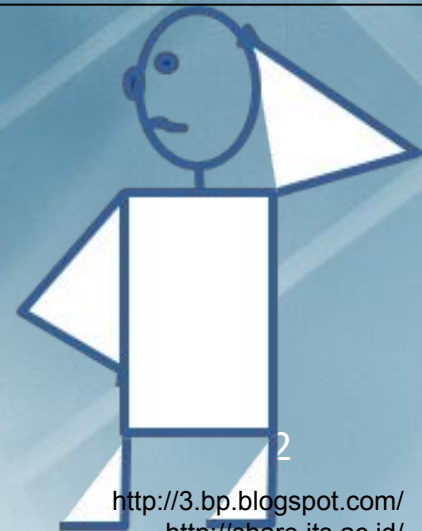


In economics literature, a distinction often is made between risk and uncertainty:

- ✓ “**risk**” is used when probabilities of possible outcomes are known or at least estimable;
- ✓ “**uncertainty**” is reserved for situations where such probabilities cannot be estimated.

“Risk is measurable
uncertainty”

“Uncertainty is unmeasurable
risk”



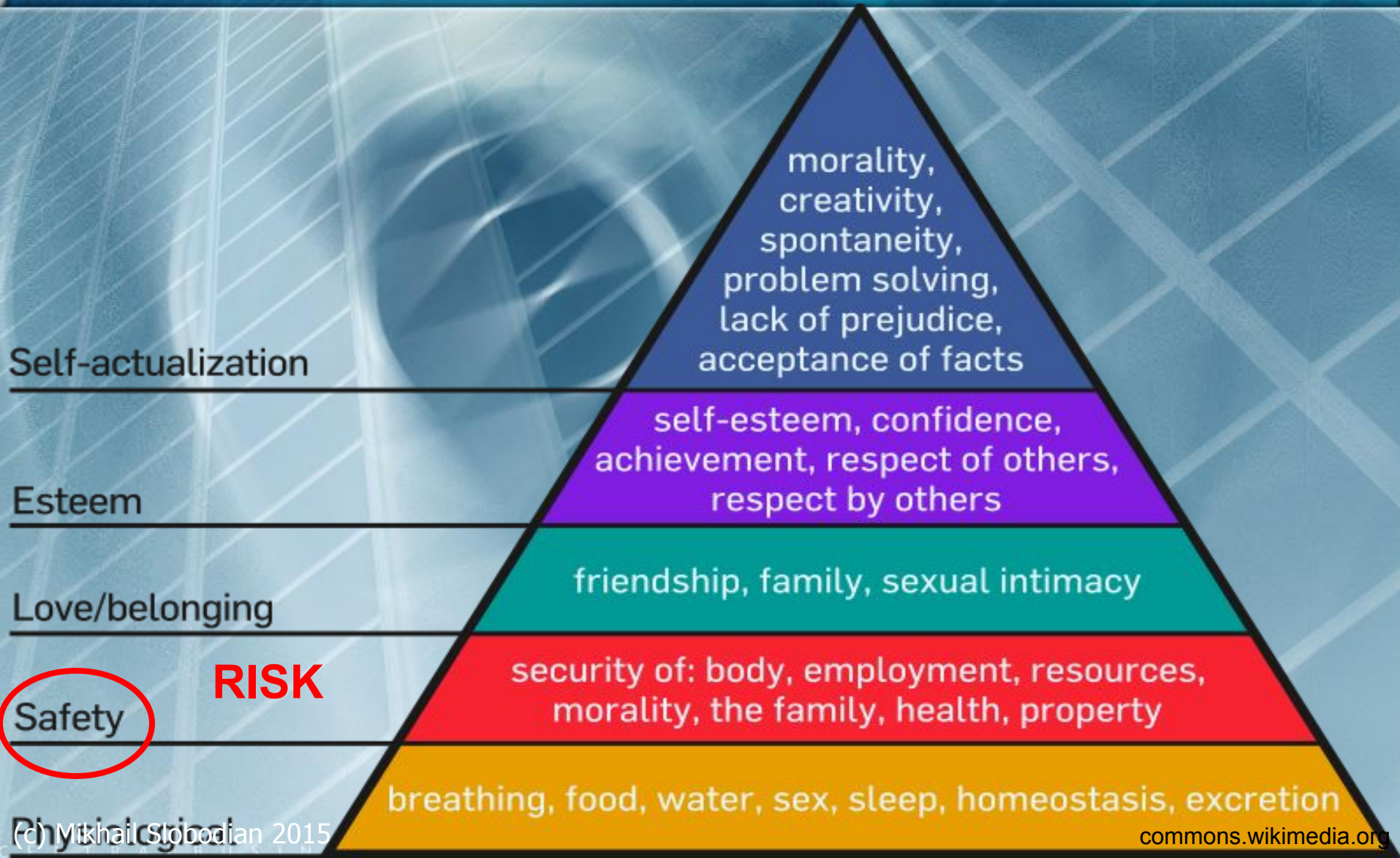
DEFINITIONS OF RISK

1. Risk equals the expected loss (Willis, 2007)
2. Risk equals the expected disutility (Campbell, 2005)
3. Risk is the probability of an adverse outcome (Graham and Weiner, 1995)
4. Risk is a measure of the probability and severity of adverse effects (Lowrance, 1976)
5. Risk is the combination of probability and extent of consequences (Ali, 2002)
6. Risk is equal to the triplet (S_j, p_j, C_j) , where S_j is the i^{th} scenario, p_j is the probability of that scenario, and C_j is the consequence of the i^{th} scenario, $i = 1, 2, ..N$ (Kaplan and Garrick, 1981; Kaplan, 1991)

DEFINITIONS OF RISK

7. Risk is equal to the two-dimensional combination of events/consequences and associated uncertainties (will the events occur, what will be the consequences) (Aven 2007a, 2008a, 2009a, 2010)
8. Risk refers to uncertainty of outcome, of actions and events (Cabinet Office, 2002)
9. Risk is potential losses associated with a hazard or an extreme event to a given place within a given period of time, which can be defined in terms of the adverse consequences (damage/losses) and the probability of occurrence (Yan J. Disaster Risk Assessment: Understanding the Concept of Risk // <http://www.gripweb.org/>).

MASLOW'S HIERARCHY OF NEEDS



THE CONCEPT OF RISK

- ✓ Risk is always the risk of something (technical facility, natural hazard) to someone (an individual, a group of people, society or all humankind).
- ✓ Risk is perceived not solely by technical parameters and probabilistic numbers, but in psychological, social and cultural context.
- ✓ Individual and social characteristics form risk perception and influence the way we react towards risks.
- ✓ Risk perception is attenuated or amplified in a typical pattern described by the psychometric paradigm.

RISKS AND RISK SUBJECTS

A **peril** is a cause of possible injury or loss at times in the future. When a peril exists, no one can know exactly which, if any, of the possible outcomes will occur. Note that the possible outcomes associated with a peril involve the occurrence or non-occurrence of injuries or losses at specific future times.

Risks can be **monetary** (having outcomes that are expressed in monetary terms) or **nonmonetary** in nature. The non-monetary risks associated with a house fire include the risk of physical damage, as well as the risks of inconvenience and emotional upset, while the monetary risks include the risk of incurring expense to repair the structure or to provide temporary housing to the occupants. Since a fire can result in damage to any part of the house and to any of the contents of the house, the list of possible outcomes for the risk of physical damage is (infinitely) long. 7

RISKS AND RISK SUBJECTS

Risks often are associated with a specific person or thing or with collections of persons and things:

- ✓ a life and health insurance risk, for instance, is associated with a specific human being;
- ✓ a collision risk is associated with a specific automobile.

A **risk subject** is a person or thing, or a collection of persons or things, associated with a risk.

PERIL AVOIDANCE AND RISK REDUCTION

Some perils can be avoided. The chance of adverse reaction to a specific vaccine, for example, can be avoided by not taking it. The risks created by other perils can be minimized. The likelihood of being injured in an airplane accident can be reduced greatly by not flying. It cannot be eliminated totally, as on rare occasions people on the ground have become victims of airplane crashes. The incidence and severity of injury or loss associated with other perils can be reduced significantly by taking appropriate safety precautions. Periodic maintenance of the electrical systems of a building, for example, may reduce the incidence of fires in that building, and both smoke detectors and automatic sprinklers may reduce the severity of fire losses. Taking such precautions may be called “risk reduction.”

TRANSFER OF RISK

Risks can result in adverse financial or personal consequences to an individual.

If available resources, such as **personal savings**, are sufficient to easily offset these consequences, additional mitigating action may not be needed.

In situations in which this is not the case, ignoring the potential impact of such risks could be undesirable. Accordingly, various approaches have been devised to mitigate such impact.

Mitigation of the adverse consequences of an uncertain event often is provided by families, friends, privately funded charities, or government assistance, among others.

Mitigation also is provided by governmental or private **insurance programs** or **prepaid service plans**.

RISK CHARACTERISTICS

Risk classification typically involves the identification of certain characteristics of the risk subject associated with the risk.

Recall that a risk subject has been defined as a person or thing, or a collection of persons or things, associated with a risk.

For many risks it is possible to observe qualities – often, but not always, quantitative in nature – associated with the risk subject or subjects that provide useful information about the likelihood of the various outcomes associated with the risk.

Observable qualities of the risk subjects that provide useful information about the risk probabilities associated with the risk are called risk characteristics.

RISK CHARACTERISTICS

Age, for example, is a quality associated with a person that provides useful information about the risk of his or her death within the next year. Not every quality associated with a risk subject provides such useful information.

For example, the solidity of construction of a car and the health of a person might provide useful information about the risks involved in collision coverage. Similarly, the health of a person might provide useful information about the risks involved in life insurance coverage. But, under most circumstances, the color of the car's upholstery is not an indicator of the likelihood or severity of a collision and the color of a person's eyes is not an indicator of longevity. Observable qualities of the risk subjects that do provide useful information about the risk probabilities associated with the risk are called **risk characteristics**.

RISK CHARACTERISTICS

The “useful information” provided by risk characteristics often will emerge from an examination of historical data. However, even if historical data are limited or unavailable, risk characteristics are often useful in grouping together risks with substantially similar risk probabilities.

The ways risk characteristics are used in a risk classification system vary. A value often is determined for each risk characteristic and the set of these values determines the risk class to which the risk is assigned.

RISK CHARACTERISTICS

In cases in which a specific quality of the risk subject can be shown to be correlated to a risk probability, the quality provides sufficient useful information for it to be used as a risk characteristic.

The existence of a persistent correlation often prompts a search for an explanation that takes the form “A causes B.” A cause and effect explanation sometimes is readily apparent. This is true, for example, for the correlation of a prior heart attack with shortened longevity.

Sometimes, however, a statistical correlation may be well-established, but a cause and effect explanation may not be evident. In such cases, introduction of additional risk characteristics might facilitate a more accurate assessment of the relevant risk probabilities.

APPROACHES TO THE CONCEPTION AND ASSESSMENT OF RISK

- ✓ the actuarial approach (using statistical predictions);
- ✓ the toxicological and epidemiological approach (including ecotoxicology);
- ✓ the engineering approach (including probabilistic risk assessment);
- ✓ the economic approach (including risk-benefit comparisons);
- ✓ the psychological approach (including psychometric analysis);
- ✓ social theories of risk;
- ✓ cultural theory of risk (using grid-group analysis).

SYSTEMATIC CLASSIFICATION OF RISK PERSPECTIVES

INTEGRATED APPROACHES (e.g., Social Amplification of Risk)							
	Actuarial Approach	All Hazards Approach	Probabilistic Risk Analysis	Economics of Risk	Psychology of Risk	Social Theories of Risk	Cultural Theory of Risk
Base Unit	Expected Value	Modelled Value	Synthesized Expected Value	Expected Utility	Subjectively Expected Value	Perceived Fairness and Competence	Shared Value
Predominant Method	Extrapoliation	Experiments Survey	Event & Fault Tree Analysis	Risk Benefit Analysis	Psychometrics	Surveys Structural Analysis	Grid-Group Analysis
Scope of Risk Concept	Universal	Universal	Safety	Universal	Individual Perceptions	Social Interests	Cultural Clusters
Basic Problem Area	One Dimensional	One Dimensional	One Dimensional	One Dimensional	Multi-Dimensional	Multi-Dimensional	Multi-Dimensional
	Averaging over space, time, context			Preference Aggregation		Social Relativism	
Major Application	Predictive Power	Transfer to Humans Intervening Variables	Common Mode Failure	Common Denominator	Social Relevance	Complexity	Empirical Validity
	Insurance	Life and Safety Protection of Property	Safety Engineering	Decision Making	Policy Making and Regulations Conflict Resolution (Mediation) Risk Communication		
Instrumental Function	Risk Sharing	Early Warning Standard Setting Improving Systems		Resource Allocation	Individual Assessment	Equity Fairness Political Acceptance	Cultural Identity
Social Function	<div style="display: flex; justify-content: space-between; align-items: center;"> <div>Assessment</div> <div>Risk Reduction and Policy Selection (Coping with Uncertainty)</div> <div>Political Legitimation</div> </div>						

APPROACHES TO THE CONCEPTION AND ASSESSMENT OF RISK

All risk concepts have one element in common:

the distinction between reality and possibility.

If this distinction is accepted, the term “**risk**” denotes the possibility **that an undesirable state of reality** (adverse effects) **may occur as a result of natural events or human activities.**

This definition implies that humans can and will make causal connections between actions (or events) and their effects, and that undesirable effects can be avoided or mitigated if the causal events or actions are avoided or modified. Risk is therefore both a descriptive and a normative concept. It includes the analysis of cause-effect relationships, which may be scientific, anecdotal, religious, or magical; but it also carries the implicit message to reduce undesirable effects through appropriate modification of the causes or, though less desirable, mitigation of the consequences.

APPROACHES TO THE CONCEPTION AND ASSESSMENT OF RISK

The definition of risk contains three elements:

- ✓ undesirable outcomes;
- ✓ possibility of occurrence;
- ✓ state of reality.

All risk perspectives provide different conceptualizations of these three elements. They are paraphrased in the following three questions:

- ✓ How can we specify or measure uncertainties?
- ✓ What are undesirable outcomes?
- ✓ What is the underlying concept of reality?

TECHNICAL RISK ANALYSES

The **actuarial approach** provides a straight-forward answer to these questions. The base unit is expected value, that is, the relative frequency of an event averaged over time.

The undesirable events are confined to physical harm to humans or ecosystems, which can be objectively observed or measured by appropriate scientific methods. An application of this approach may be the prediction of fatalities in car accidents for the coming year. The expected value can be extrapolated from the statistical data about fatal accidents in previous years.

This perspective of risk relies on two conditions:

- ✓ enough statistical data must be available to make meaningful predictions;
- ✓ the causal agents that are responsible for the negative effects must remain stable over the predicted time period.

TECHNICAL RISK ANALYSES

The assessment of health and environmental risks is similar to the actuarial analysis but differs in the method of calculating the possibility of undesirable effects.

In risk assessments, causal relationships have to be explored and modeled explicitly. Based on **toxicological** (animal experiments) **or epidemiological studies** (comparison of a population exposed to a risk agent with a population not exposed to the risk agent), researchers try to identify and quantify the relationship between a potential risk agent (such as dioxin or ionizing radiation) and physical harm observed in humans or other living organisms.

Modeling is used to isolate a causal agent from among several intervening variables. These risk assessments can serve as early warning signals to inform society that a specific substance may cause harm to humans or the environment.

TECHNICAL RISK ANALYSES

Probabilistic risk assessments attempt to predict the probability of safety failures of complex technological systems even in the absence of sufficient data for the system as a whole.

Using fault-tree or event-tree analyses, the failure probabilities for each component of the system are systematically assessed and then linked to the system structure. All probabilities of such a logical tree are then synthesized in order to model the overall failure rate of the system.




TECHNICAL RISK ANALYSES

A probabilistic risk assessment provides the same product as the actuarial analysis, that is, an average estimate of how many undesirable events one can expect over time as a result of a human activity or a technological failure. Its major problems lie in the modeling of common mode failures, that is, the simultaneous breakdown of technical components, and of human-machine interactions.

Probabilistic risk assessments have been specifically valuable in detecting deficiencies in complex technical systems and in improving the safety performance of the technical system under consideration.

TECHNICAL RISK ANALYSES

The technical analyses of risk have drawn much criticism from the social sciences:

-  what people perceive as an undesirable effect depends on their values and preferences;
-  the interactions between human activities and consequences are more complex and unique than the average probabilities used in technical risk analyses are able to capture;
-  the institutional structure of managing and controlling risks is prone to organizational failures and deficits which may increase the actual risk (the interaction between organizational malfunctions and risk is usually excluded from technical risk analyses);

TECHNICAL RISK ANALYSES



the numerical combination of magnitude and probabilities assumes equal weight for both components (the implication is indifference between high-consequence/low-probability and low-consequence/high-probability events with identical expected values).

TECHNICAL RISK ANALYSES

From the normative perspective, the practice of risk minimization implies a clear distinction between experts and laypersons.

Risk reduction or mitigation is based on the assumption that risk should be reduced in proportion to the expected or modeled harm to humans or ecosystems. This assumption is highly contested: social actions to cope with risk are not confined to the single goal of risk minimization but include other objectives such as equity, fairness, flexibility, or resilience. The inclusion of these complementary objectives requires participation by interest groups and the affected public.

TECHNICAL RISK ANALYSES

Furthermore, technical risk analyses can provide only aggregate data over large segments of the population and long time duration. Each individual, however, may face different degrees of risk depending on the variance of the probability distribution.

A person who is exposed to a larger risk than the average person may legitimately object to a risk policy based on aggregate calculations. The extent to which a person is exposed to a specific risk also rests on lifestyle factors and anecdotal knowledge, both of which are mostly unknown to scientists performing risk analyses.

The dominance of science in risk policy making provides too much power to an elite that is neither qualified nor politically legitimated to impose risks or risk management policies on a population.

ECONOMIC PERSPECTIVES ON RISK

All risk concepts of the social sciences have in common the principle that the causes and consequences of risks are mediated through social processes. The concept closest to the technical approach is the **economic concept of risk**. The major difference here is the transformation of physical harm or other undesired effects into subjective utilities.

The base unit of utilities describes the degree of satisfaction or dissatisfaction associated with a possible action or transaction. Whether physical harm is evaluated as pleasure or disaster remains irrelevant in the technical understanding of risk.

Not so in economics: the relevant criterion is the subjective satisfaction with the potential consequences rather than a predefined list of undesirable effects.

ECONOMIC PERSPECTIVES ON RISK

The shift from expected harm to expected utility serves two major purposes:

- ✓ subjective (dis)satisfaction can be measured for all consequences, including psychological or social effects that are deemed undesirable;
- ✓ the common denominator “personal satisfaction” allows a direct comparison between risks and benefits across different options.

Using utilities instead of physical harm provides a common denominator that enables each individual to compare options with different benefit profiles according to overall satisfaction.

Utility is universal and one-dimensional.

ECONOMIC PERSPECTIVES ON RISK

The economic risk concept constitutes a consistent and coherent logical framework for situations in which decisions are being made by individuals and in which decision consequences are confined to the decision maker.

Most decisions on risks are collective decisions (public or meritocratic goods), which require the aggregation of individual utilities. How to measure the welfare of society, however, remains a major problem, since the subjective nature of utility does not provide a logically valid method to aggregate individual utilities into a single societal welfare function. Averaging over expressed preferences is a common but unsatisfactory method for determining the utility of collective goods.

ECONOMIC PERSPECTIVES ON RISK

The two basic foundations of economics are the rational actor paradigm and the reliance on utilitarian ethics. People, for example, do smoke or drink, buy foolish things, or engage in activities that do not provide any utility to them.

At the same time, people show compassion for others and may seek to increase the utility of other people even at their own expense. This behavior is contrary to the naive version of the rational actor paradigm, which postulates that people with full information will act in accordance with their own interests. Economic theory is, however, compatible with a modified and more realistic version of the rational actor paradigm, which assumes that people have subjective motives for performing an action and that they try to assess consequences of their action in the light of these motives.

FUNCTIONS OF ECONOMIC APPROACH IN RISK POLICIES

- ✓ It provides techniques and instruments to measure and compare utility losses or gains from different decision options, thus enabling decision makers to make more informed choices (not necessarily better choices).
- ✓ It enhances technical risk analyses by providing a broader definition of undesirable events, which include nonphysical aspects of risk.
- ✓ Under the assumption that market prices (or shadow prices) represent social utilities, it provides techniques to measure distinctly different types of benefits and risks with the same unit.
- ✓ It includes a model for rational decision making, provided that the decision makers can reach agreement about the utilities associated with each option.

PSYCHOLOGICAL PERSPECTIVES ON RISK

The **psychological perspective** on risk expands the realm of subjective judgment about the nature and magnitude of risks in three ways:

- ✓ it focuses on personal preferences for probabilities and attempts to explain why individuals do not base their risk judgments on expected values;
- ✓ more specific studies on the perception of probabilities in decision making identified several biases in people's ability to draw inferences from probabilistic information (these biases refer to the intuitive processing of uncertainty);
- ✓ the importance of contextual variables for shaping individual risk estimations and evaluations.

THE EMERGENCE OF SYSTEMIC RISKS

The modern concept of **emerging systemic risks is devoted to** risks “that affect the systems on which the society depends – health, transport, environment, telecommunications, etc.”. Systemic risk denotes the embeddedness of risks to human health and the environment in a larger context of social, financial and economic risks and opportunities. Systemic risks are at the crossroads between natural events (partially altered and amplified by human action such as the emission of greenhouse gases), economic, social and technological developments and policy driven actions, both at the domestic and the international level.

THE EMERGENCE OF SYSTEMIC RISKS

These new interrelated risk fields also require a new form of risk analysis, in which data from different risk sources are either geographically or functionally integrated into one analytical perspective.

Investigating systemic risks goes beyond the usual agent-consequence analysis and focuses on interdependencies and spillovers between risk clusters.

INCREASING RISKS IN THE MODERN WORLD

The **demographic development**, including the increase of the world population, the growing population density and visible trends towards urbanisation accompanied by significant changes in the age structure of most industrial populations have lead to more vulnerabilities and interactions among natural, technological and habitual hazards.

Demographic changes are also partially responsible for the strong interventions of human beings into the natural environment.

INCREASING RISKS IN THE MODERN WORLD

Economic and cultural globalization. The exponential increase in international transport and trade, the emergence of world-wide production systems, the dependence on global competitiveness and the opportunities for universal information exchange testify to these changes and challenges. In terms of risks, these trends create a close web of interdependencies and coupled systems by which small perturbations have the potential to proliferate through all the more or less tightly coupled systems and cause significant damage.

INCREASING RISKS IN THE MODERN WORLD

The development of globalization is closely linked to **technological change**.

The technological development of the last decades has led to a reduction of individual risk, i.e. the probability to be negatively affected by a disaster or a health threat, yet increased the vulnerability of many societies or groups in society.

Among the characteristics of this technological development are the tight coupling of technologies with critical infrastructure, the speed of change and the pervasiveness of technological interventions into the life-world of human beings, all aspects that have been described as potential sources of catastrophic disasters.

INCREASING RISKS IN THE MODERN WORLD

In addition to the technological changes, **socioeconomic structures** have experienced basic transitions as well. In the last two decades efforts to deregulate the economy, privatize public services and reform regulatory systems have changed the government's role in relation to the private sector which had major repercussions on the procedures and institutional arrangements for risk assessment and risk management.

Attitudes and policies are increasingly influenced by international bodies with conflicting interests and increasingly by the mass media.

INCREASING RISKS IN THE MODERN WORLD

- ✓ An increase of catastrophic potential and a decrease of individual risk, associated with an increased vulnerability of large groups of the world population with respect to technological, social and natural risks.
- ✓ An increase in (cognitive) uncertainty due to the growing interconnectedness and the fast global changes.
- ✓ An increased uncertainty about a change in frequency and intensity of natural hazards due to global change.
- ✓ Strong links between physical, social and economic risks due to the interconnectedness of these systems.
- ✓ An exponential increase in payments by insurances for compensating victims of natural catastrophes.
- ✓ The emergence of “new” social risks (terrorism, disenchantment, mobbing, stress, isolation, depression).

INCREASING RISKS IN THE MODERN WORLD

- ✓ An increased importance of symbolic connotations of risks, and thus a high potential for social amplification and attenuation of risks. Social amplification of risk describes an amplification of the seriousness of a risk event caused by public concern about the risk or an activity contributing to the risk.

RISK CLASSIFICATION AND THE ESTIMATION OF EXPECTED LOSS

Estimates of the risk probabilities for a group of risks may be based on historical data regarding frequency of occurrence and severity observed for those risks, provided the risks are substantially similar to one another. When conditions are stable over time and when risk classes are sufficiently homogeneous and are expected to remain so, reliable estimates of the risk probabilities and thus of the expected loss can be based on historical data.

The relevance of data obtained from historical studies might be limited if the conditions under which the data were observed or the observed mix of risks are not those that are expected to apply to the risk probabilities being estimated. Historical information can lose relevance quickly as economic and social environments and other factors change.

DONALD RUMSFELD

RISK CLASSIFICATION

“Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know.

We also know there are known unknowns; that is to say we know there are some things we do not know.

But there are also unknown unknowns – the ones we don't know we don't know.

And if one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones.”

DONALD RUMSFELD

RISK CLASSIFICATION

- ✓ **known/known** (i.e., we know the risk exists and we know how to model the outcomes);
- ✓ **known/unknown** (i.e., we know the risk exists, but we don't know how to model it with any reliability);
- ✓ **unknown/unknown** (i.e., we have no idea what risks might exist and, by definition, no idea how to model the risks).

NEW CHALLENGES FOR RISK MANAGEMENT

- ✓ Finding more accurate and effective ways to characterize uncertainties in complex systems
- ✓ Developing methods and approaches to investigate and manage the synergistic effects between natural, technological, and behavioural hazards
- ✓ Integrating the natural and social science concepts of risks to deal with both physical hazards and social risk perceptions
- ✓ Expanding risk management efforts to include global and transboundary consequences of events and human actions