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Three decades of risk research: accomplishments and new challenges

ORTWIN RENN
Center of Technology Assessment, Industriestrasse 5, 70565 Stuttgart, Germany

Abstract

Risk research over the last three decades has been focused on the development of methods of and procedures for risk analysis and risk management. As a consequence of this research, risk management agencies have been trying to make risk assessments a routine operation for evaluating different hazards, chemical agents, or technologies. The problem with the worldwide routinization of the risk assessment methodology is, however, that formal analysis may obscure the conceptual foundations and limitations of this method and may induce a false degree of certainty when dealing with potential side-effects of human actions and interventions. One of the main tasks of the risk community should be to emphasize the necessity of integrated risk assessment and the development of innovative risk management strategies that build upon the insights of the natural, technical and social sciences. In order to integrate risk assessment and risk perception, the article analyses the strengths and weaknesses of each approach to risk analysis and highlights the potential contributions that the technical sciences and the social sciences can offer to risk management. Technical assessments provide the best estimate for judging the average probability of an adverse effect linked to an object or activity. Public perception should govern the selection of criteria on which acceptability or tolerability are to be judged. In addition, public input is needed to determine the trade-offs between criteria. Finally, public preferences are needed to design resilient strategies for coping with remaining uncertainties.

1. Introduction

Today's society seems to be preoccupied with the notion of risk. The recent examples of the so-called 'Mad Cow Disease' (BSE) in Great Britain, the Brent Spar affair, the anniversary of the infamous Chernobyl accident – to name just a few have gained much public attention and have given rise to a growing discontent between the public's desire to see risks reduced and the actual performance of risk management institutions. There is confusion about the potential of risk assessment and risk management. What can society do to reduce risks? What does the term 'risk' mean and how is this term understood among natural and social scientists, regulators, social groups, and the public at large? What is so special about risk that makes it such an important issue in contemporary politics?

There are more questions than answers when people talk about risks (Short, 1984; Renn *et al*., 1992; Dietz *et al*., 1996). The career of the term 'risk' is a rather recent

phenomenon, however (Fischhoff *et al*., 1984). Of course, risk has always been part of human existence and the field of risk research started as early as human beings started to reflect the possibility of their own death and contemplated actions to avoid dangerous situations. The mathematical tools for risk assessment were developed more than a century before actual risk analyses were performed on technical systems. However, a systematic scientific attempt to study risks in society and to professionalize risk management agencies is a rather recent addition. Several authors claim that systematic studies of risk began with Chauncy Starr's seminal article on risk and voluntariness in 1968 (Starr, 1969; Kates and Kasperson, 1983; Covello and Mumpower, 1985). Others date the beginning in the early 1950s when space exploration programmes were designed and probabilistic tools of safety analysis were developed and implemented (Kolluru, 1995). Others again associate the first risk assessment studies of chemical or nuclear power plants with the beginning of risk research (Royal Society, 1983). Whatever date one chooses, it will be in the post-World War II time period, which justifies the title of this paper claiming that we can look back at roughly three decades of systematic and scientific risk research.

What progress has been made in this time span? What contributions did the field make in understanding our world around us and make it a better place to live in? Any answers to these questions can never be more than subjective impressions given such a short time period of risk research. But it is worth while reflecting about the state of risk research and about the tasks and research challenges that still lie ahead of us even if such a review is based on personal observations and impressions.

I have structured this review in four parts. First, I shall consider risk as a concept in general, then turn to the hard sciences of risk assessment and discuss its accomplishments, challenges, and future research agenda. Then I will turn to the social sciences, most notably the economic, psychological, and sociological disciplines, and analyse their strengths and weaknesses. At the end, I will discuss the prospects and limitations in the societal efforts to cope with risks and discuss the potential contributions of the various approaches to develop a better understanding of risk and to improve risk management practice.

2. What is the meaning of the term 'risk'?

Talking about risks faces the immediate danger that everybody talks about something different (see for example: Fischhoff *et al*., 1984; Short, 1984; Renn *et al*., 1992; Vlek, 1996). There is no commonly accepted definition for the term risk – neither in the sciences nor in public understanding. All risk concepts have one element in common, however: the distinction between reality and possibility (Markowitz, 1991; Evers and Nowotny, 1987). If the future were either predetermined or independent of present human activities, the term 'risk' would make no sense. This may seem obvious but only in the context of fairly recent developments in our own culture, and contrasts sharply with more fatalistic views of nature and society. For example, a tunnel collapse in Saudi Arabia in 1990 was considered inevitable and it was assumed that the victims of this accident would have died in some other way if the accident had been prevented by human activities. If one's fate is predetermined, there is no need for anticipating future outcomes other than to please one's curiosity, because negative consequences cannot be avoided.

If the distinction between reality and possibility is acknowledged, the term 'risk' is often associated with the possibility that an undesirable state of reality (adverse effects) may occur as a result of natural events or human activities (similar in Kasperson and Kasperson, 1987: viii; Starr and Whipple, 1991: 53; almost identical to Hillgartner, 1992: 40; the same idea is expressed in more technical terms in: National Research Council, 1983; Kates and Kasperson, 1983; IEC, 1993). It may be difficult to determine, however, what characteristics are necessary to label an outcome as 'adverse' rather than 'desirable' or 'tolerable' (cf. discussion in: Renn, 1985; HMSO, 1988). In particular, if one intends to include the common use of the term 'risk' in economic theory, both gains and losses need to be subsumed under 'risk'. In addition, Machlis and Rosa pointed out that there is a phenomenon such as 'desired risk' (for example in sports activities) that people aspire to reach for experiencing a special thrill (Machlis and Rosa, 1990). Rosa hence recommended to use the term 'risk' for uncertain outcomes regardless of whether they are positive or negative (Rosa, 1996: 19). Inspired by these arguments, I have chosen the following definition. Risks refer to the *possibility that human actions or events lead to consequences that affect aspects of what humans value.*

This definition implies that humans can and will make causal connections between actions (or events). Consequences are perceived from a non-fatalistic viewpoint. They can be altered either by modifying the initiating activity or event or by mitigating the impacts (Appelbaum, 1977). 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 magic (Douglas, 1966; Wiedemann, 1993), 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.

Risk assessment is the scientific process of defining the components of risk in precise, usually quantitative terms. In technical risk assessments, this means specifying what is at stake, calculating the probabilities for (un)wanted consequences, and aggregating both components by multiplying the probabilities by the magnitude of the effects (Kolluru and Brooks, 1995: 2.3f). Risk management refers to the process of reducing the risks to a level deemed tolerable by society and to assure control, monitoring, and public communication (Morgan, 1990). Since risk refers to a potential of 'real' consequences, it is both a social construction and a representation of reality.

Thus the definition of risk contains three elements: outcomes that affect what humans value, possibility of occurrence (uncertainty), and a formula to combine both elements (Renn *et al.*, 1992). All presently used approaches to risk provide different conceptualizations of these three elements. In engineering and the physical sciences, for example, the term 'risk' is taken to be probability times consequences. In psychology, risk is rather seen as a function of subjectively perceived utilities and probabilities of their occurrence. All these definitions can be paraphrased in the following three questions:

- What are undesirable outcomes and who determines what undesirable means?
- How can we specify, qualify or quantify the possibilities of undesirable outcomes?
- How do we aggregate different classes of undesirable outcomes into a common concept that allows comparisons and the setting of priorities?

In this paper these three questions – the scope of negative effects, the conceptualization of uncertainty, and the rule of aggregation for practical purposes – serve as guiding

questions for distinguishing the different concepts of risk and discussing their present contributions and future challenges.

3. The past as a guidebook for the future: technical risk assessments

The world of the insurance companies has a simple but very effective answer to these three questions. Their reference point is the expected value, i.e. 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. First, enough statistical data must be available to make meaningful predictions. Second, the causal agents that are responsible for the negative effects must remain stable over the predicted time period (Häfele *et al.*, 1990). The resulting risk assessment is reduced to a single dimension representing an average over space, time, and context.

The answers become more complex when the adverse effects cannot be observed as an immediate effect of a causing agent. If we think of environmental risks such as dioxin, benzene or radioactive particles, the link between exposure and effect is often difficult to draw, sometimes not even measurable. In such risk assessments, causal relationships have to be explored and modelled 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 (WHO, 1977; Lave, 1987; National Research Council, 1991). Modelling is a necessary step 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 even if the effects are not obvious to an unskilled observer. In addition, dose-effect investigations help risk managers to define standards in accordance with observed or modelled threshold values. If there is no threshold value as in the case of most carcinogens, risk assessments provide information about the probability of harm depending on the dose.

Another complication is experienced when people face technological risks, i.e. the possibility of technical malfunctions or human errors in handling such machines. As a tool to model such failures and their consequences, experts use probabilistic risk assessments in an 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 (Lowrance, 1976; Hauptmanns *et al.*, 1987; Morgan, 1990, IAEA, 1995). 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. A probabilistic risk assessment provides the same product as the actuarial analysis on which insurance data is based, i.e. an average estimate of how many undesirable events one can expect over time as a result of a human activity or a technological failure.

Several problems are associated with this approach to calculate risks of accidents (IAEA, 1995). It has been proven to be difficult to model common mode failures, i.e. the simultaneous breakdown of technical components. Second, human-machine interactions are difficult to predict. They often rely on idiosyncratic events that defy systematic modelling. Other problems arise when social events interact with technological systems, such as terrorist attacks, sabotage, social unrest, or breakdown of organizational order (for example alcohol-drinking air pilots or drug-taking nuclear power plant operators). Hard data based on statistical trends is usually not available for interactions between the social and the technological system. Most assessments rely on expert judgments for such events or omit them from the analysis. Using expert judgments is still more valid than pure intuition but there is considerable doubt about the predictive power of these models. In spite of these difficulties, probabilistic risk assessments have been specifically valuable to detect deficiencies in complex technical systems and to improve the safety performance of the technical system under consideration. Examples are chemical plants, power plants, or liquid gas installations.

These three approaches to risk (actuarial, environmental, and technological) have much in common and can be grouped together as technical perspectives on risk. They anticipate potential physical harm to human beings, cultural artifacts or ecosystems, average these events over time and space, and use relative frequencies (observed or modelled) as a means to specify probabilities. The normative implication is obvious: since physical harm is perceived as an undesirable effect (at least for most people and society as a whole), technical risk analyses can be used to reveal, avoid, or modify the causes that lead to these unwanted effects. They can also be used to mitigate consequences, if causes are yet unknown, remote from human intervention, or too complex to modify. Their instrumental functions in society are, therefore, oriented to risk sharing and risk reduction, through mitigation of consequences, standard setting, and improvements in the reliability and safety of technological systems. In addition, the data from technical risk analyses are a crucial input for conducting risk-benefit analyses. For this purpose, the physical damage has to be converted in monetary values. This will be described in more detail in the section on economic approaches to risk.

4. A critical review of the technical concepts and challenges for the future

The technical analyses of risk have drawn much criticism from the social sciences (Hoos, 1980; Douglas, 1985; Beck, 1986;1992, Freudenburg, 1989; Shrader-Frechette, 1991; Reiss, 1992) . First, what people perceive as an undesirable effect, depends on their values and preferences (Dietz *et al*., 1996). Second, 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 (Fischhoff *et al*., 1982). Third, the institutional structure of managing and controlling risks is prone to organizational failures and deficits which may increase the actual risk (Perrow, 1984; Short and Clarke, 1992). The interaction between organizational malfunctions and risk is usually excluded from technical risk analyses. Fourth, risk analysis cannot be regarded as a value-free scientific activity (Fischhoff, 1995). Values are reflected in how risks are characterized, measured, and interpreted. Fifth, 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. However, people show distinct preferences for one or the other (Slovic, 1987; Renn, 1990). Most people prefer a risk that will kill a few people at a time rather than a risk that kills many people at once. 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 (Hattis and Kennedy, 1990; Nowotny and Eisikovic, 1990). A person who is exposed to a larger risk than the average person may legitimately object to a risk policy based on aggregate calculations (Jasanoff, 1993: 127). 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.

How valid are the criticisms by social scientists? In my opinion, all the critical remarks are well taken and point to the problem that technical risk analyses represent a narrow framework that should not be the single criterion for risk identification, evaluation, and management. Technical risk analysis rests on many conventions (Weinberg, 1972), such as the selection rules for identifying undesirable effects, the choice of a probability concept and the equal weighting of probability and magnitude. All of these conventions in risk analyses can be defended through logical reasoning, but they represent only parts of what individuals and society experience as risk.

This does not mean that technical risk analyses are unnecessary or less relevant than broader concepts of risk. They do serve a major purpose. After all, people are getting hurt or killed in accidents, in natural disasters, or through pollution (Shrader-Frechette, 1991: 30). I agree with Jim Short who insists that risk cannot be confined to perceptions and social constructions alone, but that objective outcomes in terms of injuries, fatalities, and other types of losses are an integral part of the social processing of risk (Short, 1989; Rosa, 1998). Technical risk analyses help decision makers to estimate the expected physical harm. They provide the best knowledge about actual damage that is logically or empirically linked with each possibility of action. Cancer, for example, is caused by exposure to a harmful agent, such as benzene, and the effects are a function of the dose. In addition, for events that can be observed and repeated, probabilities are adequate tools to model their likelihood of occurrence in the future.

In terms of the three guiding questions stated above, technical analyses rely on relative frequencies as a means to express probabilities. This definition excludes unexpected events and aggregates data over space, populations and time. The undesired effects are confined to physical harm to humans and the ecosystems, thus excluding social and cultural impacts. The narrowness of this approach constitutes both its weakness and its strength. Abstracting a single variable from the context of risk-taking makes the concept of risk one-dimensional but also universal. Confining undesirable consequences to physical harm excludes other consequences that people might also regard as undesirable, but physical harm may be the only consequence that (almost) all social groups and cultures agree is undesirable (Douglas and Wildavsky, 1982; Schwarz and Thompson, 1990; Thompson *et al.*, 1990) .

Looking into the next decades of technical risk analysis, it is obvious to me that we need to continue our efforts to improve the methodology for risk assessments and to standardize procedures and techniques in order to enhance the spectrum of risk events that we can include in the analysis and to make sure that risk managers are able to

understand and use wisely the instruments that risk analysts have developed over recent decades. Technical risk analysis has matured to become a sophisticated and powerful tool in coping with potential harm of human actions or natural events (Morgan, 1995). Its application, however, in risk management is far from reflecting this power and professionalism. In addition to better practical manuals for risk analyses, I can see three major targets for the next decades (cf: Brown and Goble, 1990; Kolluru and Brooks, 1995; Morgan, 1995):

- widening the scope of effects for using risk assessment, including chronic diseases (rather than focusing only on fatal diseases such as cancer or heart attack); risks to ecosystem stability (rather than focusing on a single species); and social risks of crime and urbanization;
- addressing risk at a more aggregate and integrated level, such as studying synergistic effects of several toxins or constructing a risk profile over a geographic area that encompasses several risk causing facilities;
- studying the variations among different populations, races, and individuals and getting a more adequate picture of the ranges of sensibilities with respect to environmental pollutants, lifestyle factors, stress levels, and impacts of noise;
- integrating risk assessments in a comprehensive technology assessment or problem solving exercise so that the practical values of its information can be phased into the decision making process at the needed time and that its inherent limitations can be compensated through additional methods of data collection and interpretation;
- developing more forgiving technologies that tolerate a large range of human error and provide sufficient time for initiating counteractions.

5. A new perspective: risk is what matters to people

As much as technical risk analysis is needed, it does not question the need for social science studies on risk. The exclusion of social context and meaning from technical risk analyses provides an abstraction that enhances the intersubjective validity of the results but at the price of neglecting the costs and other dimensions of social processing of risk experiences (Brehmer, 1987). 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 what economists have coined 'utilities' (Just *et al*., 1982; Smith, 1986). The base unit of utility 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. The objective yardstick for measuring utility in economics is the amount of money somebody is willing to pay for a change that provides a higher degree of utility than remaining at the status quo.

The shift from expected harm to expected utility serves two major purposes. First, subjective (dis)satisfaction can be measured for all consequences, including

psychological or social effects that are deemed undesirable. Second, and more important, the common denominator 'personal satisfaction' allows a direct comparison between risks and benefits across different options (Merkhofer, 1984). The question: 'How safe is safe enough?' cannot be answered by the three technical concepts unless there is a threshold of exposure between zero risk and some risk or the benefit of each option is identical (if so you should choose the one with the lowest risk). 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 (Derby and Keeney, 1981). Several economists deduct the collective utility by looking at past behaviour (revealed preferences), others use surveys or auctions to determine the balance between the utility lost by implementing the risk and the utility gained by receiving fringe benefits or direct compensation (expressed preferences).

If risks can be expressed in terms of utilities, which some authors contest (cf. the debate between Kelman, 1981 and Butters *et al.*, 1981), they can be integrated into a decision process in which costs and benefits are assessed and compared. Since risks denote possible costs rather than actual costs, they have to be weighted by the probability of their occurrence. Furthermore, since risks and benefits may not materialize until years after implementing the desired option, the consequences have to be discounted over time (Hyman and Stiftel, 1988). Choosing the correct discount rate has been a major challenge to economists. Since market interest rates hardly reflect time preferences for collective risks, discount rates must be deliberately set according to theoretical reasoning or empirical surveys. There is also the ethical question whether a loss of life can be discounted at all. Notwithstanding all these problems, economic theory attempts to integrate risk analysis as part of a larger cost-benefit consideration in which risks are the expected utility losses resulting from an event or an activity. The ultimate goal is to allocate resources so as to maximize their utility for society (Smith, 1986, Shrader-Frechette, 1991).

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. In the risk area both conditions are rarely met. First, most decisions on risks are collective decisions (public or meritocratic goods), which require the aggregation of individual utilities. How to aggregate individual utilities into a single societal welfare function remains an open problem in economics until this day. Second, many transactions between individuals imply the imposition of risks on third parties, who may not benefit or only marginally benefit from the transaction itself (MacLean, 1986). These problems are aggravated by the fact that utilities are often measured in monetary units, which are perceived as incommensurable with the risk of serious health impediments or even death (Baram, 1980). In spite of these criticisms, the economic approach serves several vital functions in risk policies:

1. 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).
2. It enhances technical risk analyses by providing a broader definition of undesirable and desirable outcomes, which include non-physical aspects of risk.
3. 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. Such balancing of risks and benefits do not necessarily require monetary units. Alternative expressions such as 'quality adjusted life years' may also serve as yardsticks for measuring the net utility balance.

4. It includes a model for rational decision making, provided that the decision makers can reach agreement about the utilities associated with each option.

In terms of the three guiding questions, the economic concept of risk is based on probabilities, a social definition of undesirable effects based on individual utilities, and the treatment of these effects as real gains or losses to individuals or society. In contrast to the technical approaches, probabilities are not only conceptualized as relative frequencies but also as strength of beliefs (Fischhoff *et al.*, 1981). Furthermore, people show different preferences when combining subjective probabilities and utilities depending on their basic attitudes towards taking risks (Kahneman and Tversky, 1979).

Again we might ask what the economic analysis of risk has contributed to our understanding of risk and the improvement of risk policies. First, the treatment of risk in economics has sharpened our vision for conceptualizing risk as a cost factor that can be exchanged, treated or mitigated just like any other cost factor. The mental processing of uncertainty is not confined to calculating expected values (probabilities times magnitude), but is part of an individual cost-benefit-analysis in which risk avoidance as well as risk proneness may be a prudent response when selecting the best option from a variety of possibilities. Economic rationality implies that different risk attitudes are legitimate elements of any risk calculation (Luce and Weber, 1986). This is true for speculating on the stock market as well as for coping with natural hazards. Second, economic studies on risk have demonstrated the opportunities and limits of exchanging different types of costs and offering compensation (Kunreuther, 1995). Perceived risks to one's health or even life are almost impossible to compensate with monetary compensation, at least in an industrial country. At the same time, however, risk insurance as well as liability laws act as powerful incentives for risk managers to avoid future damages as a means to save money. A large portion of the legal activities in the United States is devoted to *ex post* compensation of victims for being involuntarily exposed to a risk.

Looking into the next decades of risk research in the field of economics, I would like to stress three main targets for a future research agenda:

- to develop models and empirical evidence for specifying the role and required structures of insurance and liability legislation as policy tools for voluntary risk reduction and more reliable risk management practice;
- to improve the methodologies for contingent valuation of adverse effects and provide better policy tools for aggregating different risk experiences into commonly acceptable measures of public welfare (utilities);
- to develop new models and procedures for balancing risks and benefits, including new compensation schemes and benefit sharing programmes.

6. Risk perception: the wisdom of the lay public

The psychological perspective on risk expands the realm of subjective judgment about the nature and magnitude of risks in three ways. First, it focuses on personal preferences for probabilities and attempts to explain why individuals do not base their risk

Table 1. Intuitive biases of risk perception

Biases	*Description*
Availability	Events that come to people's mind immediately are rated as more probable than events that are less mentally available.
Anchoring effect	Probabilities are adjusted to the information available or the perceived significance of the information.
Representativeness	Singular events experienced in person or associated with properties of an event are regarded as more typical than information based on frequencies.
Avoidance of cognitive dissonance	Information that challenges perceived probabilities that are already part of a belief system will either be ignored or downplayed.

Table 2. The four semantic images of risk in public perception

1. *Pending danger (Damocles Sword)*
- artificial risk source
- large catastrophic potential
- inequitable risk-benefit distribution
- perception of randomness as a threat

2. *Slow killers (Pandora's Box)*
- (artificial) ingredient in food, water, or air
- delayed effects; non-catastrophic
- contingent on information rather than experience
- quest for deterministic risk management
- strong incentive for blame

3. *Cost-benefit ratio (Athena's Scale)*
- confined to monetary gains and losses
- orientation towards variance of distribution rather than expected value
- asymmetry between risks and gains
- dominance of probabilistic thinking

4. *Avocational thrill (Hercules' Image)*
- personal control over degree of risk
- personal skills necessary to master danger
- voluntary activity
- non-catastrophic consequences

judgments on expected values (Lopes, 1983; Luce and Weber, 1986). An interesting result of these investigations was the discovery of consistent patterns of probabilistic reasoning that are well suited for most everyday situations. People are risk averse if the potential losses are high and risk prone if the potential gains are high (Kahneman and Tversky, 1979). Second, 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 are summarized in Table 1 (Festinger, 1957; Kahneman and Tversky, 1974; Ross, 1977; Renn, 1990)

Risk managers and public health professionals should be aware of these biases because they are found in public perception and may be one of the underlying causes for the observed public response. For example, the frequent media coverage about 'Mad Cow Disease' (BSE) and a potential link to a certainly fatal human disease has alarmed the public and promoted a response of outrage based on the availability bias. Yet the question remains, why most people seem to underestimate the probability of contracting such a disease while amplifying the dread associated with the individual suffering from the disease. In order to understand this response, one needs to understand the semantic images that govern people's risk perception.

This brings us to the third major insight of risk perception research. Psychological research has revealed different meanings of risk depending on the context in which the term is used (Renn, 1989, 1990). Whereas in the technical sciences the term risk denotes the probability of the effect multiplied by the magnitude of the effect, as I have stated above, the everyday use of risk has different connotations. With respect to technological risk Table 2 illustrates the main semantic images.

Risk as a pending danger (Damocles sword)

Risk is seen as a random threat that can trigger a disaster without prior notice and without sufficient time to cope with the hazard involved. This image is linked to artificial risk sources with large catastrophic potential. The magnitude of the probability is not considered. It is rather the randomness itself that evokes fear and avoidance responses. Natural disasters, in contrast, are perceived as regularly occurring and thus predictable or related to a special pattern of occurrence (causal, temporal or magic). The image of pending danger is therefore particularly prevalent in the perception of large-scale technologies. Nuclear power plants are a prime example of this semantic category.

Slow killers (Pandora's Box)

Risk is seen as an invisible threat to one's health or well-being. Effects are usually delayed and affect only few people at the same time. Knowledge about these risks is based on information by others rather than on personal experience. These risks pose a major demand for trustworthiness in those institutions that provide information and manage the hazard. If trust is lost, people demand immediate actions and assign blame to these institutions even if risks are very small. Typical examples of this risk class are food additives, pesticides, and radioactive substances. Due to the importance of trust in monitoring and managing slow killers, risk managers should place a major effort to improve their trustworthiness and credibility in the community.

Cost-benefit ratio (Athena's Scale)

Risks are perceived as a balancing of gains and losses. This concept of risk comes closest to the technical understanding of risk. However, this image is only used in peoples' perceptions of monetary gains and losses. Typical examples are betting and gambling, both of which require sophisticated probabilistic reasoning. People are normally able to perform such probabilistic reasoning but only in the context of gambling, lotteries, financial investment, and insurance. Laboratory experiments show that people orient

their judgment about lotteries more towards the variance of losses and gains than towards the expected value.

A vocational thrill (Hercules' theme)

Often risks are actively explored and desired (Machlis and Rosa, 1990). These risks include all leisure activities for which personal skills are necessary to master the dangerous situation. The thrill is derived from the enjoyment of having control over one's environment or oneself. Such risks are always voluntary and allow personal control over the degree of riskiness.

This list of risk concepts demonstrates that the intuitive understanding of risk is a multidimensional concept and cannot be reduced to the product of probabilities and consequences. Risk perceptions differ considerably among social and cultural groups. However, it appears to be a common characteristic in almost all countries, in which perception studies have been performed, that most people perceive risk as a multidimensional phenomenon and integrate their beliefs with respect to the nature of the risk, the cause of the risk, the associated benefits, and the circumstances of risk-taking into one consistent belief system.

In terms of the three guiding questions, the psychological perspective on risk includes all undesirable or desirable effects that people associate with a specific cause. Whether these cause-effect relationships reflect real dangers or gains, is irrelevant. Individuals respond according to their perception of risk and not according to an objective risk level or the scientific assessment of risk. Scientific assessments influence the individual response to risk only to the degree that they are integrated in the individual perceptions (Covello, 1983). Furthermore, relative frequencies or other (scientific) forms of defining probabilities are substituted by the strength of belief that people have about the likelihood of any undesirable effect occurring (Fischhoff *et al.*, 1981). Both aspects are combined in a formula that normally puts more weight on the magnitude of the effects than on the probability of their occurrence. The main insight is, however, that effects and likelihood are enriched by the perceived presence of situational and risk specific characteristics that depend on properties such as the degree of perceived personal control, the perception of a social rather than an individual risk, or the familiarity of the risk situation (Slovic *et al.*, 1981; Vlek and Stallen, 1981; Gould *et al.*, 1988).

The focus on the individual and his/her subjective estimates is also the major weakness of the psychological perspective (Mazur, 1987; Plough and Krimsky, 1987; Thompson *et al.*, 1990). The broadness of the dimensions that people use to make judgments and the reliance on intuitive heuristics and anecdotal knowledge make it hard, if not impossible, to aggregate individual preferences and to find a common denominator for comparing individual risk perceptions. Risk perceptions vary among individuals and groups. Whose perceptions should be used to make decisions on risk? At the same time, however, these perceptions reflect the real concerns of people and include the undesirable effects that the technical analyses of risk often miss. Facing this dilemma, how can risk perception studies contribute to improving risk policies? They can:

- reveal public concerns and values;
- serve as indicators for public preferences;

- document desired lifestyles;
- help to design risk communication strategies;
- represent personal experiences in ways that may not be available to the scientific assessment of risk.

In essence, the psychological studies can help to create a more comprehensive set of decision options and to provide additional knowledge and normative criteria to evaluate them (Fischhoff, 1985). Similar to the other perspectives, the psychological perspective on risk contributes valuable information for understanding risk responses and for designing risk policies, but it is limited in its comprehensiveness and applicability.

What are the new challenges of psychological risk research for the next decades? Again I foresee three main targets for risk perception studies:

- to focus on inter-individual differences and commonalities among populations, nations, and cultural groups;
- to study the impact of the risk-taking context and its situational implications for risk perception and risk evaluation;
- to improve our knowledge of the links between risk perception, attitudes towards risk objects, and actual behaviour.

Risk perception has widened our view for the mental processing of risk information and for the common as well as unique coping mechanisms that people use in dealing with uncertain outcomes. These coping mechanisms may occasionally be misleading or inappropriate in many instances, but they do serve a vital role in providing a counterbalance to the purely technical analysis of risk assessments. There may be good reasons that evolution has provided human beings with a multidimensional, sophisticated (but on each dimension rather fuzzy) concept of risk. This concept favours cautious approaches to new risks and induces little concern about risks to which everyone is already accustomed (Shrader-Frechette, 1991). It places relevance on aspects such as control and possibility for mitigation, both aspects that have been proven helpful in situations where predictions went wrong.

7. A further complication: social learning of risk and institutional responses

The risk world becomes even more complex when the sociological or cultural concepts of risks are added to the psychological concepts. The sociological perspectives include undesirable events that are socially defined and in (some cases) socially constructed. 'Real' consequences are always mediated through social interpretation and linked with group values and interests (Bradbury, 1989; Dietz *et al*., 1989; Shrader-Frechette, 1991; Short, 1989; Wynne, 1992). Possibilities for future events are not confined to the calculation of probabilities but encompass group-specific knowledge and vision. Furthermore, possibilities are shaped by human interventions, social organizations, and technological developments (Freudenburg, 1989; Short and Clarke, 1992). Ignoring the connections between social organizations and technological performance may seriously underestimate the likelihood of failures. Lastly, reality is seen as both a system of physical occurrences (independent of human observations) and constructed meanings with respect to these events and to abstract notions, such as fairness, vulnerability, and justice (Kasperson and Kasperson, 1983; MacLean, 1986; Linnerooth-Bayer and Fitzgerald, 1996).

The sociological perspective illuminates the need to base risk policies on the experience of inequities, unfairness and – to a less degree – perceived organizational incompetence (Perrow, 1984; Short, 1984; Stallings, 1987; Dietz *et al.*, 1996). These three experiences are not the only social consequences that matter to most people, but they are probably the most important in conjunction with perceived health impairments. Many of the psychological perception variables, such as personal control and voluntariness, reflect the same concern. As a consequence, sociological studies can help to address the issues of fairness and competence and provide normative conclusions for legitimizing risk policies (Wynne, 1984). However, these conclusions will vary considerably depending on the cultural context in which such a legitimation is introduced.

In recent years, anthropologists and cultural sociologists have suggested that social responses to risks are determined by prototypes of cultural belief patterns; i.e. clusters of related convictions and perceptions of reality (Douglas and Wildavsky, 1982; Rayner, 1992; Schwarz and Thompson, 1990; Thompson *et al.*, 1990; Dake, 1991). Whereas the sociological analysis of risk links social judgments about risks to individual or social interests and values, the cultural perspective assumes that cultural patterns structure the mindset of individuals and social organizations to adopt certain values and reject others. Organizations or social groups belonging to the *entrepreneurial* prototype perceive risk taking as an opportunity to succeed in a competitive market and to pursue their personal goals. They are less concerned about equity issues and would like the government to refrain from extensive regulation or risk management efforts. This group contrasts most with organizations or groups belonging to the *egalitarian* prototype, which emphasizes cooperation and equality rather than competition and freedom. Egalitarians focus on long term effects of human activities and are more likely to abandon an activity (even if they perceive it as beneficial to them) than to take chances. They are particularly concerned about equity. The third prototype, i.e. the *bureaucrats,* relies on rules and procedures to cope with uncertainty. As long as risks are managed by a capable institution and coping strategies have been provided for all eventualities, there is no need to worry about risks. The fourth prototype, the group of *atomized or stratified individuals,* principally believe in hierarchy, but they miss group identity and a system of social bonding. These people trust only themselves, are often confused about risk issues, and are likely to take high risks for themselves, but oppose any risk that they feel is imposed on them. At the same time, however, they see life as a lottery and are often unable to link harm to a concrete cause.

There has been an intensive debate in recent years about the validity of these prototypical descriptions in terms of theoretical reasoning and empirical evidence (Nelkin, 1982; Johnson, 1987; Funtowicz and Ravetz, 1985; Shrader-Frechette, 1991; Rosa, 1998). This is not the place to review the evidence and to evaluate the theoretical or empirical soundness of cultural theory (see also Renn *et al.*, 1992). Whatever the 'real' cultural patterns may be, cultural analysis has demonstrated to the risk professionals that the concept of risk assessment as well as the rationale behind it cannot claim universal validity and legitimizing power among all groups and cultures. There are different worldviews that determine how different groups cope with the universal experience of potential outcomes of actions and events. Different worldviews include different knowledge structures and value systems. For example, the selection of physical harm as the basic indicator for risk may seen irrelevant for a culture in which violations of religious beliefs are perceived as the main risks in society.

As valuable as cultural studies on risk have been in showing the relativity of scientific reasoning in the social and cultural context of processing risk information, they also carry the danger of solipsism, i.e. the belief that all knowledge about the state of the world is relative to its spectator and thus not applicable to anyone else (Rayner, 1987: 6f; Searle, 1995; Rosa, 1998). This view of collective knowledge is not only theoretically difficult to defend, it is also empirically invalid. Even everyday experience tells us the opposite daily. Almost all cultures are concerned about avoiding physical harm and, without any doubt, modern societies are strongly concerned about heath impacts and ecological damage. Whatever and whoever causes such risks, is likely to receive societal attention. Hardly anybody opposes research that looks into the causing mechanisms of cancer and almost every one expects scientists to study these causes on the basis of commonly approved and tested methodologies and techniques. The results of these studies may be contested on the grounds that the methodology was weak or inappropriate (inner-scientific debate), but it may also be claimed that the rationale used to study the phenomenon is inappropriate or insufficient from a different cultural perspective (such as questioning the statistical significance test when applying epidemiological methods). Furthermore, arguments used in one cultural context may convince almost everyone within this context (such as a specific scientific community), but may completely fail to convince any member of another community.

One recent attempt to integrate ontological realism and social construction of risk experience has been the framework of social amplification and attenuation of risk (Kasperson *et al.*, 1988; Renn *et al.*, 1992). In 1988, Kasperson and colleagues proposed a novel approach to study the social experience of risk. The concept of social amplification and attenuation of risk is based on the thesis that events pertaining to hazards interact with psychological, social, institutional, and cultural processes in ways that can heighten or attenuate individual and social perceptions of risk and shape risk behaviour. Behavioural patterns, in turn, generate secondary social or economic consequences that extend far beyond direct harm to humans or the environment, including significant indirect impacts such as liability, insurance costs, loss of trust in institutions, or alienation from community affairs. Amplification and attenuation differ among individuals in their roles as private citizens and in their roles as employees or members of social groups and public institutions. The metaphor of social amplification and attenuation can serve as a communication tool to highlight the dualism of risk as an objective threat and a social construction. Studies on psychological perception, social influences and cultural preferences can be integrated in the amplification – attenuation framework.

Another major insight from the social science studies on risk has been the importance of procedure or due process for making decisions (Renn *et al.*, 1993). People are not only concerned about the risks that are imposed on them but also about the process by which the decision has been made. In particular, they demand that those affected by a decision will also have the opportunity to be involved in the decision making process. While in many European countries, the legal process of involvement is structured by law and does not leave many choices in the selection of processes or participants, the American tradition of participation is less rigid in structure and encourages public expectations that, without prior consent, decisions cannot be implemented. Insufficient public involvement is often a cause for litigation and political protest. Litigation, however, is not only costly and time-consuming, it often results in unsatisfactory resolutions of the conflict, since the legal system is not prepared to adequately

cope with problems in which highly technical aspects are at the centre of the controversy. In the United States and recently also Europe, procedures of mediation have gained more and more popularity as a means to incorporate public concerns into the decision process without sacrificing technical expertise or rational reasoning (Amy, 1987). Mediation is also less expensive and time-consuming than litigation. Risk managers should therefore be aware that risk reduction may not be at the heart of a risk controversy but rather the process by which decisions on risks were made. In democratic societies, people demand procedural fairness and expect risk management institutions to demonstrate that fair procedures have been used.

In terms of the three guiding questions, cultural and sociological analysis implies that the definition of desirability or undesirability of outcomes, the generation and estimation of possibilities as well as the formulas to combine both aspects depend on the social context and the cultural affiliation of the respective social group (Shubik, 1991). It is my belief that sociological and cultural analysis will be of vital importance for the next decades in risk research. Society is experiencing an increase in pluralism of values, lifestyles, and knowledge systems (Beck, 1992). Many philosophers and social scientists claim that communication between these pluralist groups has become more and more difficult and is likely to become impossible in the near future (Luhmann, 1990; 1991). Since the experience of risk spans the boundaries of confined social groups, communication is a prerequisite for risk management and policy implementation. It is thus essential to provide semantic and organizational tools for creating a common language base among and between different groups and to find new means of mediation and conflict resolution among the different stakeholders (Webler, 1995).

Based on these considerations, my recommendation for the social and cultural sciences are focused on two major challenges:

- to understand the different rationales and concepts of risk within and between different cultures and social groups and to develop tools of communication that are able to bridge these differences;
- to develop and experiment with new models of mediation, participation, and conflict resolution that help risk researchers and risk managers to find a commonly acceptable understanding of the respective risk problem among the potentially affected constituents and to develop methods for discourse that assist in developing risk policies as a means to reduce physical harm as well as experiences of inequity, value violation or lifestyle disturbance.

8. Where to go from here: an attempt to integrate risk concepts

What is the major lesson to be learned from this review of risk concepts? Technical analysis provides society with a narrow definition of undesirable effects and confines possibilities to numerical probabilities based on relative frequencies. However, this narrowness is a virtue as much as it is a shortcoming. Focused on 'real' health effects or ecological damage, technical analyses are based on a societal consensus of undesirability or desirability and a (positivistic) methodology that assures equal treatment for all risks under consideration (Merkhofer, 1984).

The other perspectives on risk broaden the scope of undesirable effects, include other ways to express possibilities and likelihood, and expand the understanding of reality to

include the interpretations of outcomes and 'socially constructed' realities. The social experience of risk includes the perception of actual damage, but it is more focused on the evaluation of the risk context and the associations between the risk and social or cultural artifacts (Otway and von Winterfeldt, 1982). Integrating all these perspectives in order to do justice to the phenomenon of risk in our society appears to be necessary for both the analysis of risk experience and the prescription of risk policies. While few would dispute that the observed risk behaviour of individuals and groups is puzzling enough to get the social and cultural sciences involved, many feel that risk policies should be based solely on technical and economic considerations.

This would indeed be appropriate if society were only concerned about risk minimization. If all society would care about is to reduce the amount of physical harm done to its members, technical analyses and economic balancing would suffice for effective risk management. Included could be the perspective of organizational sociology to make sure that technical safety measures are paralleled by institutional control and monitoring. The social sciences would only be needed to sell the risk management packages to the 'misinformed' public via risk communication.

However, society is not only concerned with risk minimization (Douglas and Wildavsky, 1982; Schwarz and Thompson, 1990). People are willing to suffer harm if they feel it is justified or if it serves other goals. At the same time, they may reject even the slightest chance of being hurt if they feel the risk is imposed on them or violates their other attitudes and values (Fischhoff *et al*., 1985; MacLean, 1986). Context matters. So does the procedure of decision making independent of outcome. Responsive risk management needs to take these aspects into account. The social science perspectives on risk can help to enrich risk management. They can:

- identify and explain public concerns associated with the risk source;
- explain the context of risk-taking situations;
- identify cultural meanings and associations linked with special risk arenas;
- help to articulate objectives of risk policies in addition to risk minimization, such as enhancing fairness and institutional trust and reducing inequities and vulnerability;
- design procedures or policies to incorporate these cultural values into the decision making process;
- design programmes for participation and joint decision making;
- design programmes for evaluating risk management performance and organizational structures for identifying, monitoring, and controlling risks.

The above discussion, however, demonstrates, that the inclusion of the social science perspectives for normative use in policy making faces two major drawbacks. First, the advice of social scientists will vary considerably depending on the worldview and disciplinary background of the individuals asked. Second, unlike the technical or economic perspective, the social science concepts offer no common denominator for measuring cultural or social acceptability. What constitutes a value violation for one group, may be perfectly in line with the values of another group. Who is going to decide which social construction of reality has more validity than another competing construction?

Risk policies can cope with the first problem by employing different perspectives in analysing the situation and by knowing the relative advantages and disadvantages of each perspective. The second problem creates more difficulties. It is obvious that a

simple or even complex algorithm of multi-dimensional decision making would not resolve the potential conflicts between competing social constructions (although formal multi-attribute decision analysis may provide an excellent framework for structuring problems and decision options within a single social and cultural context). There is also no impartial referee available to judge the appropriateness of cultural constructions. The only viable resolution of these conflicts in democratic societies is by initiating a discourse among the major parties involved in the decision making process or affected by the decision outcomes (Stolwijk and Canny, 1991; Renn *et al.*, 1993). The recent report by the US Academy of Sciences on risk characterization has emphasized the need for such open discourses (cf. Stern and Fineberg, 1996). A dialogue with the public can be organized in the form of advisory committees, citizen panels, formal hearings, and others. Democratic values can provide the means by which to construct this dialogue and the social science perspectives can help to make these forms of dialogue work, i.e. to make sure that each group can bring their own interest and values to the process and yet reach a common understanding of the problem and the potential solutions (Fiorino, 1989). Participation is not only a normative goal of democracy, it is also a requirement for rational decision making in situations in which risks need to be evaluated.

Risk management implies value judgments on three levels. The first set of value judgments refers to the list of criteria on which acceptability or tolerability should be judged, the second set of value judgments determines the trade-offs between criteria, and the third set of values should assist in finding resilient strategies for coping with remaining uncertainties. Using informed consent on all three value inputs does not place any doubt on the validity and necessity of applying the best of technical expertise for defining and calculating the performance of each option on each criterion. The magnitude of risks should reflect technical expertise as best as possible, since 'real' victims are at stake. Setting priorities within risk management, however, would imply having social or political forces determine the criteria of judging tolerable levels of risk, whereby the technical assessments are used as one important input among others to compare different options. Public input is hence a crucial contribution for determining the objectives of risk policies and for weighing the various criteria that ought to be applied when evaluating different options.

For the next decades, risk research still has a full agenda. As much as technical analysis needs to broaden its scope of research targets as well as improve handling of uncertainty, the social sciences must inform policy makers about public concerns, develop better methods of mutual communication, and provide models for the type of discourse needed to bring the technical analyses in line with the social and cultural needs of the respective societies (cf. Fischhoff, 1995; Morgan, 1995). The dual nature of risk as a potential for physical change and as a social construction demands a dual strategy for risk management. Public values and social concerns may act as the driving agents for identifying those topics for which risk assessments are judged necessary or desirable. There is no shortage of new problems and challenges in risk research. I hope we will have the professional skills, the demanded creativity and ingenuity, and the energy and ethics necessary to meet those challenges.

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