Chapter 1
White Paper on Risk Governance: Toward an Integrative Framework[1]

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Purpose and Objectives of This White Paper

This document aims to guide the work of the International Risk Governance Council and its various bodies in devising comprehensive and transparent approaches to 'govern' a variety of globally relevant risks. Globally relevant risks include *transboundary* risks, i.e. those that originate in one country and affect other countries (such as air pollution), *international* risks, i.e. those that originate in many countries simultaneously and lead to global impacts (such as carbon dioxide emissions for climate change) and ubiquitous risks, i.e. those that occur in each country in similar forms and may necessitate a co-ordinated international response (such as car accidents or airline safety). To this end the document and the framework it describes provide a common *analytic structure for investigating and supporting the treatment of risk issues* by the relevant actors in society. In doing so, the focus is not restricted to how governmental or supranational authorities deal with risk but equal importance is given to the roles of the corporate sector, science, other stakeholders as well as civil society – and their interplay. The analytic structure will, it is hoped, facilitate terminological and conceptual clarity, consistency and transparency in the daily operations of IRGC and assure the feasibility of comparative approaches in the governance of risks across a broad range of hazardous events and activities. In particular, this document is meant to assist members of IRGC in their tasks to provide scientifically sound, economically feasible, legally and ethically justifiable and politically acceptable advice to IRGC's targeted audiences. It is also to support IRGC in its effort to combine the best available expertise in the respective field with practical guidance for both risk managers and stakeholders.

[1] This chapter is the main body of a complete work with the same title published by IRGC in 2005. The IRGC document contains in addition three brief case studies and a series of appendices detailing other risk governance schemes. It can be downloaded from our website: http://www.irgc.org/spip/IMG/pdf/IRGC_WP_No_1_Risk_Governance_(reprinted_version).pdf

O. Renn and K. Walker (eds.), Global Risk Governance: Concept and Practice Using the IRGC Framework, 3–73.

The overall objective of this document is to establish a comprehensive and consistent yet flexible prototype analytic framework and unified set of guidance for improved risk governance. This framework integrates the following components:

- harmonised terminology with respect to key terms and concepts;
- a robust and coherent concept of framing and characterising the essential physical as well as social elements of coping with risks, including both the classic components (i.e. risk assessment, risk management and risk communication) as well as the contextual aspects such as a wider framework of risk appraisal, governance structure, risk perception, regulatory style and organisational capacity;
- a categorisation and enhancement of approaches to risk assessment and risk management including suggestions for basic safety principles and integrated appraisal and management strategies based on scientific analysis, precautionary considerations and vulnerability assessment;
- inclusion of risk-benefit evaluation and risk-risk tradeoffs;
- a conceptual framework for integrating civil society (stakeholders from the corporate sector, NGOs, associations, science communities as well as representatives of the public) in risk governance;
- principles of 'good' risk governance;
- requirements for improving risk governance capacity including the new perspective of integrated disaster risk management (IDRM).

This document draws on an initial compilation and critical review of work already available in this area (e.g. existing risk taxonomies and, in particular, guidance documentation on risk and risk governance) as well as on an acknowledgement of commonalities and differences between these approaches. A selection of these guidelines, manuals, standards, government reports etc. is summarised in annexes to the original document which may be downloaded from IRGC's website (see Footnote 1). A glossary defining the terms and concepts used throughout this White Paper may be found at the end of the chapter.

Target Audience of This White Paper

The primary audience of this document is IRGC itself which will use it as an analytic blueprint for its further work and will implement its recommendations within future IRGC projects. After a period of intense testing within several IRGC projects and empirical analysis of its use in different risk contexts and cultural environments, it is anticipated that a further revised version of this White Paper can offer assistance and guidance to senior risk managers and decision makers as well as risk practitioners outside of IRGC in their daily efforts to identify, assess, manage and monitor risk.

An important niche could, for instance, derive from the active transfer and dissemination of this body of knowledge to key actors in politics and society in developing countries and those in transition. Many of these countries are only now starting to formally think about issues of risk governance and IRGC's providing

them with relevant information and knowledge could provide valuable insights and, possibly, help them to avoid some of the pitfalls inherent in dealing with risk. A flexible yet harmonised framework might also be of benefit to both the government and industry sectors in OECD countries, since its main thrust is to provide logically coherent and sensible guidance for conducting risk appraisals (including risk assessment as well as concern assessment), for steering risk management and for improving risk governance structures in a variety of risk areas and socio-political cultures. Therefore, this document particularly addresses all those actors who will benefit from more direct cooperation with other stakeholders and from integrated risk governance procedures. Indeed, specifying the role of these actors within an integrated framework of risk governance is one of the main goals of IRGC, and this goal has also inspired the framework presented in this document. While it is clear that each risk field or 'case' under consideration is different in that it requires further specifications and adjustments, it is nonetheless hoped that the framework presented herein can serve as a 'default option' from which one can and should deviate if necessary.

Scope of the Proposed Framework

This document covers a wide range of both risks and governance structures. **Risk** is understood in this document as an uncertain consequence of an event or an activity with respect to something that humans value (definition originally in: Kates et al. 1985: 21). Risks always refer to a combination of two components: the likelihood or chance of potential consequences and the severity of consequences of human activities, natural events or a combination of both. Such consequences can be positive or negative, depending on the values that people associate with them. IRGC is not covering all risk areas but confines its efforts to (predominantly negatively evaluated) risks that lead to physical consequences in terms of human life, health, and the natural and built environment. It also addresses impacts on financial assets, economic investments, social institutions, cultural heritage or psychological well-being as long as these impacts are associated with the physical consequences.[2] In addition to the strength and likelihood of these consequences, the framework emphasises the distribution of risks over time, space and populations. In particular, the timescale of appearance of adverse effects is very important and links risk governance to sustainable development (delayed effects).

In this document we distinguish risks from **hazards**. Hazards describe the potential for harm or other consequences of interest. These potentials may never even materialise if, for example, people are not exposed to the hazards or if the targets are made resilient against the hazardous effect (such as immunisation). In conceptual terms, hazards characterise the *inherent properties of the risk agent and related*

[2] Although IRGC focuses on physical risks and their secondary implications, the framework may also be extended to allow for the investigation of financial, social or political risks as primary risk consequences.

processes, whereas risks describe the *potential effects that these hazards are likely to cause on specific targets such as buildings, ecosystems or human organisms and their related probabilities*.

Table 1 provides a systematic overview of the sources of risks or hazards that potentially fall within the scope of IRGC's work programme. The purpose of this overview is to lay out the variety of sources of risks rather than to claim that the categories proposed are exhaustive or mutually exclusive (see review of classification in Morgan et al. 2000). Furthermore, IRGC places most attention on risk areas of global relevance (i.e. transboundary, international and ubiquitous risks) which additionally include large-scale effects (including low-probability, high-consequence outcomes), require multiple stakeholder involvement, lack a superior decision-making authority and involve the potential to cause wide-ranging concerns and outrage.

The IRGC has as one of its primary responsibilities the provision of expertise and practical advice in dealing with a novel type of risk, which the OECD has labelled '**systemic risks**' (OECD 2003). This term denotes the embeddedness of any risk to human health and the environment in a larger context of social, financial and economic consequences and increased interdependencies both across risks and between their various backgrounds. 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. These new interrelated and interdependent risk fields also require a new form of handling risk, in which data from different risk sources are either geographically or functionally integrated into one analytical perspective. Handling systemic risks requires a holistic approach to hazard identification, risk assessment, concern assessment, tolerability/acceptability judgements and risk management. Investigating systemic risks goes beyond the usual agent-consequence analysis and focuses on interdependencies and spill-overs between risk clusters.

Risk in a Broader Context

The focus on risk should be seen as a segment of a larger and wider perspective on how humans transform the natural into a cultural environment with the aims of improving living conditions and serving human wants and needs (Turner et al. 1990). These transformations are performed with a purpose in mind (normally a benefit to those who initiate them). When implementing these changes, intended (or tolerated) and unintended consequences may occur that meet or violate other dimensions of what humans value. Risks are not taken for their own sake; rather more they are, actively or passively, incurred because of their being an integral factor in the very activity that is geared towards achieving the particular human need or purpose. In this context, it is the major task of risk assessment to identify and explore, preferably in quantitative terms, the types, intensities and likelihood of the (normally undesired)

Table 1 Risks taxonomy according to hazardous agents.

- **Physical Agents**
  - Ionising radiation
  - Non-ionising radiation
  - Noise (industrial, leisure, etc.)
  - Kinetic energy (explosion, collapse, etc.)
  - Temperature (fire, overheating, overcooling)
- **Chemical Agents**
  - Toxic substances (thresholds)
  - Genotoxic/carcinogenic substances
  - Environmental pollutants
  - Compound mixtures
- **Biological Agents**
  - Fungi and algae
  - Bacteria
  - Viruses
  - Genetically modified organisms
  - Other pathogens
- **Natural Forces**
  - Wind
  - Earthquakes
  - Volcanic activities
  - Drought
  - Flood
  - Tsunamis
  - (Wild) fire
  - Avalanche
- **Social-Communicative Hazards**
  - Terrorism and sabotage
  - Human violence (criminal acts)
  - Humiliation, mobbing, stigmatising
  - Experimentation with humans (such as innovative medical applications)
  - Mass hysteria
  - Psychosomatic syndromes
- **Complex Hazards (Combinations)**
  - Food (chemical and biological)
  - Consumer products (chemical, physical, etc.)
  - Technologies (physical, chemical, etc.)
  - Large constructions such as buildings, dams, highways, bridges
  - Critical infrastructures (physical, economic, social-organisational and communicative)

consequences related to a risk. In addition, these consequences are associated with special concerns that individuals, social groups or different cultures may attribute to these risks. They also need to be assessed for making a prudent judgement about the tolerability or acceptability of risks. Once that judgement is made, it is the task of risk management to prevent, reduce or alter these consequences by choosing appro-

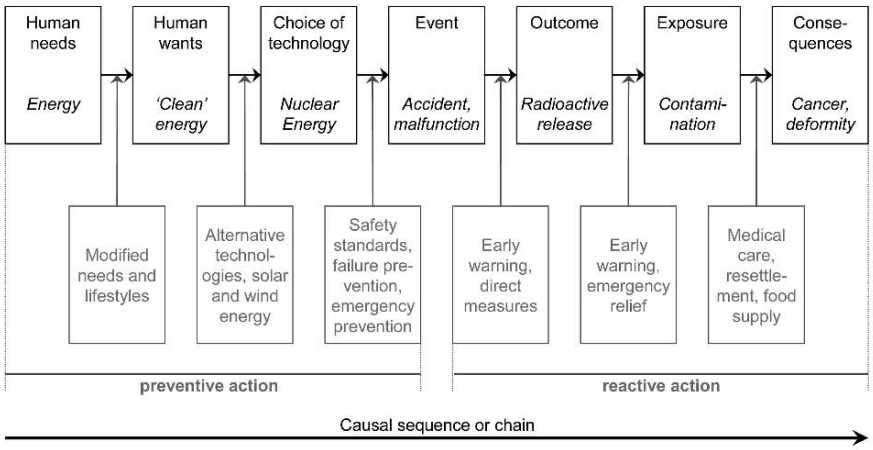

Fig. 1 Seven steps of a risk chain: The example of nuclear energy (from Hohenemser et al. 1983).

priate actions. As obvious as this distinction between risk and concern assessment (as a tool of gaining knowledge about risks) and risk management (as a tool for handling risks) appears at first glance, the *distinction becomes blurred* in the actual risk governance process.

This blurring is due to the fact that assessment starts with the respective risk agent or source and tries to both identify potential damage scenarios and their probabilities and to model its potential consequences over time and space, whereas risk management oversees a much larger terrain of potential interventions (Stern and Fineberg 1996; Jasanoff 1986: 79f; 2004). Risk management may alter human wants or needs (so that the agent is not even created or continued). It can suggest substitutes or alternatives for the same need. It can relocate or isolate activities so that exposure is prevented, or it can make risk targets less vulnerable to potential harm. Figure 1 illustrates this larger perspective for technological risks and lists the possible intervention points for risk management (taken from Hohenemser et al. 1983). Risk assessment and management are therefore not symmetrical to each other: management encompasses a much larger domain and may even occur before assessments are performed. It is often based on considerations that are not affected by or part of the assessment results. In more general terms, risk management refers to the creation and evaluation of options for initiating or changing human activities or (natural and artificial) structures with the objective being to increase the net benefit to human society and prevent harm to humans and what they value. The identification of these options and their evaluation is guided by systematic and experiential knowledge gained and prepared for this purpose by experts and stakeholders. A major proportion of that relevant knowledge comprises the results of risk assessments. However, risk managers also need to act in situations of 'non-knowledge' or insufficient knowledge about potential outcomes of human actions or activities.

The most complex questions emerge, however, when one looks at how society and its various actors actually handle risk. In addition to knowledge gained through risk assessments and/or option generation and evaluation through risk management, the decision-making structure of a society is itself highly complicated and often fragmented. Apart from the structure itself – the people and organisations that share responsibility for assessing and managing risk – one must also consider the need for sufficient organisational capacity to create the necessary knowledge and implement the required actions, the political and cultural norms, rules and values within a particular societal context and the subjective perceptions of individuals and groups. These factors leave their marks on the way risks are treated in different domains and socio-political cultures. To place risk within a context of – sometimes closely interwoven – decision-making structures such as those prevalent in governments and related authorities, in the corporate sector and industry, in the scientific community and in other stakeholder groups is of central concern to IRGC.

In the last decade the term '**governance**' has experienced tremendous popularity in the literature on international relations, comparative political science, policy studies, sociology of environment and technology as well as risk research.[3] On a national scale, *governance describes structures and processes for collective decision-making involving governmental and non-governmental actors* (Nye and Donahue 2000). Governing choices in modern societies is seen as an interplay between governmental institutions, economic forces and civil society actors (such as NGOs). At the global level, *governance embodies a horizontally organised structure of functional self-regulation encompassing state and non-state actors bringing about collectively binding decisions without superior authority* (cf. Rosenau 1992; Wolf 2002). In this perspective non-state actors play an increasingly relevant role and become more important, since they have decisive advantages of information and resources compared to single states.

It is useful to differentiate between *horizontal and vertical governance* (Benz and Eberlein 1999; Lyall and Tait 2004). The horizontal level includes the relevant actors in decision-making processes within a defined geographical or functional segment (such as all relevant actors within a community, region, nation or continent); the vertical level describes the links between these segments (such as the institutional relationships between the local, regional and state levels).

'*Risk governance*' involves the 'translation' of the substance and core principles of governance to the context of risk and risk-related decision-making. In IRGC's understanding, risk governance includes the totality of actors, rules, conventions, processes, and mechanisms concerned with how relevant risk information is collected, analysed and communicated and management decisions are taken. Encompassing the combined risk-relevant decisions and actions of both governmental and private actors, risk governance is of particular importance in, but not restricted to, situations where there is no single authority to take a binding risk management decision but where, instead, the nature of the risk requires the collaboration of, and co-ordination

[3] According to Rhodes (1996) there are six separate uses of the term governance: as minimal state, as corporate governance, as new public management, as good governance, as social-cybernetic systems and as self-organised networks.

between, a range of different stakeholders. Risk governance however not only includes a multifaceted, multi-actor risk process but also calls for the consideration of contextual factors such as institutional arrangements (e.g. the regulatory and legal framework that determines the relationship, roles and responsibilities of the actors and co-ordination mechanisms such as markets, incentives or self-imposed norms) and political culture, including different perceptions of risk.

When looking at risk governance structures it is not possible to include all the variables that may influence the decision-making process; there are too many. Therefore it is necessary to limit one's efforts to those factors and actors that, by theoretical reasoning and/or empirical analysis, are demonstrably of particular importance with respect to the outcome of risk governance. IRGC has highlighted the following aspects of risk governance which extend beyond risk assessment and risk management:

- the structure and function of various actor groups in initiating, influencing, criticising and/or implementing risk policies and decisions;
- risk perceptions of individuals and groups;
- individual, social and cultural concerns associated with the consequences of risk;
- the regulatory and decision-making style (political culture);
- the requirements with respect to organisational and institutional capabilities for assessing, monitoring and managing risks (including emergency management).

In addition to these analytical categories, this document also addresses best practice and normative aspects of what is needed to improve governance structures and processes (EU 2001a). With respect to best practice it is interesting to note that often risk creators, in particular when directly affected by the risk they generate, engage in risk reduction and avoidance out of self-interest or on a voluntary basis (e.g. industry 'gentleman's agreements', self-restriction, industry standards). Other stakeholders' efforts in risk governance therefore have to be coordinated with what is tacitly in place already. The emphasis here is on cooperative models of public-private partnerships forming a governance system that aims at effective, efficient and fair risk management solutions.[4]

Before Assessment Starts

Risks are *mental 'constructions'* (OECD 2003: 67). They are not real phenomena but originate in the human mind. Actors, however, creatively arrange and reassemble signals that they get from the 'real world' providing structure and guidance to an ongoing process of reality enactment.[5] So risks represent what people observe in

[4] Excluded from this document are such topics as crisis intervention, crisis communication, emergency planning and management and post-accidental relief. They will be covered in a separate document at a later stage.

[5] I am indebted to Gene Rosa for giving me guidance on keeping a healthy balance between a relativist and realist version of risk. For further reading refer to Rosa (1998). It should be noted

reality and what they experience. The link between risk as a mental concept and reality is forged through the experience of actual harm (the consequence of risk) in the sense that human lives are lost, health impacts can be observed, the environment is damaged or buildings collapse. The invention of risk as a mental construct is contingent on the belief that human action can prevent harm in advance. Humans have the ability to design different futures, i.e. construct scenarios that serve as tools for the human mind to anticipate consequences in advance and change, within constraints of nature and culture, the course of actions accordingly.

The status of risk as a mental construct has major implications on how risk is looked at. Unlike trees or houses, one cannot scan the environment, identify the objects of interest, and count them. Risks are created and selected by human actors. What counts as a risk to someone may be an act of God to someone else or even an opportunity for a third party. Although societies have over time gained experience and collective knowledge of the potential impacts of events and activities, one cannot anticipate all potential scenarios and be worried about all the many potential consequences of a proposed activity or an expected event. By the same token, it is impossible to include all possible options for intervention. Therefore societies have been *selective* in what they have chosen to be worth considering and what to ignore (Thompson et al. 1990; Douglas 1990; Beck 1994: 9ff.). Specialised organisations have been established to monitor the environment for hints of future problems and to provide early warning of some potential future harm. This selection process is not arbitrary. It is guided by cultural values (such as the shared belief that each individual life is worth protecting), by institutional and financial resources (such as the decision of national governments to spend money or not to spend money on early warning systems against highly improbable but high-consequence events) and by systematic reasoning (such as using probability theory for distinguishing between more likely and less likely events or methods to estimate damage potential or distribution of hazards in time and space).

Based on these preliminary thoughts, a systematic review of risk-related actions needs to start with an analysis of what major societal actors such as e.g. governments, companies, the scientific community and the general public select as risks

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that this White Paper takes no stand on the *controversial issue of constructivism versus realism of evidence and values* (this topic is extensively reviewed in Mayo and Hollander 1991, specific positions in Bradbury 1989; Douglas 1990; Shrader-Frechette 1991b; 1995; Wynne 1992; Laudan 1996; Jasanoff 2004). Whether the evidence collected represents human ideas about reality or depicts representations of reality is of no importance for the distinction between evidence and values that is suggested throughout the document. Handling risks will inevitably be directed by evidence claims (what are the causes and what are the effects?) and normative claims (what is good, acceptable and tolerable?). It is true that providing evidence is always contingent on existing normative axioms and social conventions. Likewise, normative positions are always enlightened by assumptions about reality (Ravetz 1999). The fact that evidence is never value-free and that values are never void of assumptions about evidence does not compromise the need for a functional distinction between the two. For handling risks one is forced to distinguish between what is likely to be expected when selecting option x rather than option y, on one hand, and what is more desirable or tolerable: the consequences of option x or option y, on the other hand. It is hence highly advisable to maintain the classic distinction between evidence and values and also to affirm that justifying claims for evidence versus values involves different routes of legitimisation and validation.

and what types of problems they label as risk problems (rather than opportunities or innovation potentials, etc.). In technical terms this is called '**framing**'. Framing in this context encompasses the selection and interpretation of phenomena as relevant risk topics (Tversky and Kahneman 1981; van der Sluijs et al. 2003; Goodwin and Wright 2004). The process of framing is already part of the governance structure since official agencies (for example food standard agencies), risk and opportunity producers (such as the food industry), those affected by risks and opportunities (such as consumer organisations) and interested bystanders (such as the media or an intellectual elite) are all involved and often in conflict with each other when framing the issue. What counts as risk may vary among these actor groups. Consumers may feel that all artificial food additives pose a risk, whereas industry may be concerned about pathogens that develop their negative potential due to the lack of consumer knowledge about food storage and preparation. Environmental groups may be concerned with the risks of industrial food versus organic food. Whether a consensus evolves about what requires consideration as a relevant risk depends on the legitimacy of the selection rule. The acceptance of selection rules rests on two conditions: first, all actors need to agree with the *underlying goal* (often legally prescribed, such as prevention of health detriments, or guarantee of an undisturbed environmental quality, for example purity laws for drinking water); secondly, they need to agree with the *implications derived from the present state of knowledge* (whether and to what degree the identified hazard impacts the desired goal). Even within this preliminary analysis, dissent can result from conflicting values as well as conflicting evidence, and, in particular, from the inadequate blending of the two. Values and evidence can be viewed as the two sides of a coin: the values govern the selection of the goal whereas the evidence governs the selection of cause-effect claims. Both need to be properly investigated when analysing risk governance but it is of particular importance to understand the values shaping the interests, perceptions and concerns of the different stakeholders as well as to identify methods for capturing how these concerns are likely to influence, or impact on, the debate about a particular risk. The actual measurements of these impacts should then be done in the most professional manner, including the characterisation of uncertainties (Keeney 1992; Pidgeon and Gregory 2004; Gregory 2004).

A second part of the pre-assessment phase concerns the institutional means of *early warning and monitoring*. Even if there is a common agreement of what should be framed as (a) risk issue(s), there may be problems in monitoring the environment for signals of risks. This is often due to a lack of institutional efforts to collect and interpret signs of risk and deficiencies in communication between those looking for early signs and those acting upon them. The recent tsunami catastrophe in Asia provides a more than telling example of the discrepancy between the capability to have early warning systems and the decision to install or use them. It is therefore important to look at early warning and monitoring activities when investigating risk governance.

In many risk governance processes, information about risks are pre-screened and then allocated to different assessment and management routes. In particular, industrial risk managers search for the most efficient strategy to deal with risks. This in-

cludes prioritisation policies, protocols for dealing with similar causes of risks, and optimal models combining risk reduction and insurance. Public risk regulators often use pre-screening activities to allocate risks to different agencies or to pre-defined procedures. Sometimes risks may seem to be less severe and it may be adequate to cut short risk or concern assessment. In a pending crisis situation, risk management actions may need to be taken before any assessment is even carried out. A full analysis should therefore include provisions for *risk screening* and the selection of different routes for risk assessment, concern assessment and risk management. This aspect has been called '*risk assessment policy*' in the Codex Alimentarius. It is meant to guide the assessment process in terms of assessment and management protocols, methods of investigation, statistical procedures and other scientific conventions used in assessing risks or selecting risk reduction options. A screening process may also be employed when characterising risks according to complexity, uncertainty and ambiguity as we will explain later.

Another major component of pre-assessment is the *selection of conventions and procedural rules* needed for a comprehensive scientific appraisal of the risk, i.e. for assessing the risk and the concerns related to it (see below). Any such assessment is based on prior informed yet subjective judgements or conventions articulated by the scientific community or a joint body of risk assessors and managers. Those judgements refer to (Pinkau and Renn 1998; van der Sluijs et al. 2004: 54ff.):

- the social definition of what is to be regarded as adverse, (for example by defining the 'No Adverse Effect Level' in food (NOAEL));
- the selection rule determining which potentially negative effects should be considered in the risk governance process knowing that an infinite number of potential negative outcomes can be theoretically connected with almost any substance, activity, or event;
- the aggregation rule specifying how to combine various effects within a one-dimensional scale, for example early fatalities, late fatalities, cancer, chronic diseases and so on;
- the selection of the testing and detection methods which are presently used in risk assessment, for example the use of genomics for calculating risk from transgenic plants;
- the selection of valid and reliable methods for measuring perceptions and concerns;
- the determination of models to extrapolate high dose effects to low dose situations, for example linear, quadro-linear, exponential or other functions or assumptions about thresholds or non-thresholds in dose-response relationships;
- the extrapolation of the results of animal data to humans;
- assumptions about exposure or definition of target groups;
- the handling of distributional effects which may cover inter-individual, inter-group, regional, social, time-related and inter-generational aspects.

These judgements reflect the consensus among the experts or are common products of risk assessment and management (for example by licensing special testing methods). Their incorporation in guiding scientific analyses is unavoidable and this does

not discredit the validity of the results. Yet it is essential that risk managers and interested parties are informed about these conventions and understand their rationale. On one hand knowledge about these conventions can lead to a more cautious apprehension of what the assessments mean and imply, on the other hand they can convey a better understanding of the constraints and conditions under which the results of the various assessments hold true.

In summary, Table 2 provides a brief overview of the four components of pre-assessment. The table also lists some indicators that may be useful as heuristic tools when investigating different risk governance processes. The choice of indicators is not exhaustive and will vary depending on risk source and risk target. Listing the indicators serves the purpose of illustrating the type of information needed to perform the task described in each step. The title 'pre-assessment' does not mean that these steps are always taken before assessments are performed. Rather they are logically located in the forefront of assessment and management. They should also not be seen as sequential steps but as elements that are closely interlinked. As a matter of fact, and depending on the situation, early warning might precede problem framing.[6]

Risk Assessment

The purpose of risk assessment is the generation of knowledge linking specific risk agents with uncertain but possible consequences (Lave 1987; Graham and Rhomberg 1996). The final product of risk assessment is an estimation of the risk in terms of a probability distribution of the modelled consequences (drawing on either discrete events or continuous loss functions). The different stages of risk assessment vary from risk source to risk source. Many efforts have been made to produce a harmonised set of terms and conceptual phase-model that would cover a wide range of risks and risk domains (cf. Codex Alimentarius 2001; National Research Council 1982, 1983; Stern and Fineberg 1996; EU 2000, 2003).[7] The most recent example is the risk guidance book by the International Programme on Chemical Safety (IPCS) and WHO (IPCS and WHO 2004). Although there are clear differences in structuring the assessment process depending on risk source and organisational culture, there is an agreement on basically three core components of risk assessment:

- an identification and, if possible, estimation of hazard;
- an assessment of exposure and/or vulnerability;
- an estimation of risk, combining the likelihood and the severity of the targeted consequences based on the identified hazardous characteristics and the exposure/vulnerability assessment.

[6] It should also be noted that early warning may of course also benefit from 'non-systematic' findings and incidental/accidental reporting.

[7] An extended review of a large variety of risk taxonomies is summarised in Annex A to the original White Paper, downloadable from our website:
http://www.irgc.org/spip/IMG/pdf/IRGC_WP_No_1_Risk_Governance_(reprinted_version).pdf

Table 2 Components of pre-assessment in handling risks.

Pre-assessment Components	**Definition**	**Indicators**
1 Problem framing	Different perspectives of how to conceptualise the issue	• dissent or consent on goals of selection rule • dissent or consent on relevance of evidence • choice of frame (risk, opportunity, fate)
2 Early warning	Systematic search for new hazards	• unusual events or phenomena • systematic comparison between modelled and observed phenomena • novel activities or events
3 Screening (risk assessment and concern assessment policy)	Establishing a procedure for screening hazards and risks and determining assessment and management route	• screening in place? • criteria for screening: – hazard potential – persistence – ubiquity, etc. • criteria for selecting risk assessment procedures for: – known risks – emergencies, etc. • criteria for identifying and measuring social concerns
4 Scientific conventions for risk assessment and concern assessment	Determining the assumptions and parameters of scientific modelling and evaluating methods and procedures for assessing risks and concerns	• definition of no adverse effect levels (NOAEL) • validity of methods and techniques for risk assessments • methodological rules for assessing concerns

As we have seen before, it is crucial to distinguish between hazards and risks. Correspondingly, **identification** (i.e. establishing cause-effect link) and **estimation** (determining the strength of the cause-effect link) need to be performed for hazards and risks separately. The estimation of risk depends on an exposure and/or vulnerability assessment. **Exposure** refers to the contact of the hazardous agent with the target (individuals, ecosystems, buildings, etc.).**Vulnerability** describes the various degrees of the target to experience harm or damage as a result of the exposure (for example: immune system of target population, vulnerable groups, structural deficiencies in buildings, etc.). In many cases it is common practice to combine hazard

and risk estimates in scenarios that allow modellers to change parameters and include different sets of context constraints.

The basis of risk assessment is the systematic use of analytical – largely probability-based – methods which have been constantly improved over the past years. Probabilistic risk assessments for large technological systems, for instance, include tools such as fault and event trees, scenario techniques, distribution models based on Geographic Information Systems (GIS), transportation modelling and empirically driven human-machine interface simulations (IAEA 1995; Stricoff 1995). With respect to human health, improved methods of modelling inter-individual variation (Hattis 2004), dose-response relationships (Olin et al. 1995) and exposure assessments (USEPA 1997) have been developed and successfully applied. The processing of data is often guided by inferential statistics and organised in line with decision analytic procedures. These tools have been developed to generate knowledge about cause-effect relationships, estimate the strength of these relationships, characterise remaining uncertainties and ambiguities and describe, in quantitative or qualitative form, other risk or hazard related properties that are important for risk management (IAEA 1995; IEC 1993). In short, risk assessments specify what is at stake, calculate the probabilities for (un)wanted consequences, and aggregate both components into a single dimension (Kolluru 1995: 2.3f). In general, there are five methods for calculating probabilities:

- collection of statistical data relating to the performance of a risk source in the past (actuarial extrapolation);
- collection of statistical data relating to components of a hazardous agent or technology. This method requires a synthesis of probability judgements from component failure to system performance (probabilistic risk assessments, PRA);
- epidemiological or experimental studies which are aimed at finding statistically significant correlations between an exposure of a hazardous agent and an adverse effect in a defined population sample (probabilistic modelling);
- experts', or decision makers' best estimates of probabilities, in particular for events where insufficient statistical data is available (normally employing Bayesian statistical tools);
- scenario techniques by which different plausible pathways from release of a harmful agent to the final loss are modelled on the basis of worst and best cases or estimated likelihood for each consequence at each knot).

All these methods are based either on the past performance of the same or a similar risk source or an experimental intervention. The possibility that the circumstances of the risk situation vary over time in an unforeseeable way and that people will thus make decisions in relation to changing hazards – sometimes they may even change in an unsystematic, unpredictable manner – leads to unresolved or remaining uncertainty (second order uncertainty). One of the main challenges of risk assessment is the systematic characterisation of these remaining uncertainties. They can partly be modelled by using inferential statistics (confidence interval) or other simulation methods (such as Monte Carlo), but often they can only be described in qualitative terms. Risk analysts consequently distinguish between *aleatory and epistemic un-*

certainty: epistemic uncertainty can be reduced by more scientific research[8] while aleatory uncertainty will remain fuzzy regardless of how much research is invested in the subject (Shome et al. 1998). Remaining uncertainties pose major problems in the later stages of risk characterisation and evaluation as well as risk management since they are difficult to integrate in formal risk-benefit analyses or in setting standards.

There is no doubt that risk assessment methods have matured to become sophisticated and powerful tools in coping with the potential harm of human actions or natural events (Morgan 1990). Its worldwide application, however, in dealing and managing risks is far from reflecting this degree of power and professionalism. At the same time, there are new challenges in the risk field that need to be addressed by the risk assessment communities. These challenges refer to (cf. Brown and Goble 1990; Hattis and Kennedy 1990; Greeno and Wilson 1995; Renn 1997):

- 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 the secondary and tertiary risk impacts that are associated with the primary physical risks;
- addressing risk at a more aggregated 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 assessment in a comprehensive technology assessment or option appraisal so that the practical value 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; and
- developing more forgiving technologies that tolerate a large range of human error and provide sufficient time for initiating counteractions.

Table 3 lists the three generic components of risk assessment and provides an explanation for the terms as well as a summary list of indicators that can be used in the different risk contexts for performing the respective task. As with Table 2, the choice of indicators is not exhaustive and serves the purpose of illustrating the type of information needed to perform the task described in each step. The three components are normally performed sequentially but, depending on circumstances, the order may be changed. Often, exposure assessments are done before hazards are

[8] There are many tools available to model epistemic uncertainty. The Dutch guidance document on uncertainty assessment and communication lists the following tools: sensitivity analysis, error propagation methods, Monte Carlo Analysis, NUSAP (numeral, unit, spread, assessment, pedigree), expert elicitation, scenario analysis, PRIMA (pluralistic framework of integrated uncertainty management and risk analysis) and checklists for model quality assistance (van der Sluijs et al. 2004).

Table 3 Generic components of risk assessment.

Assessment Components	Definition	Indicators
1 Hazard identification and estimation	Recognising potential for adverse effects and assessing the strength of cause-effect relationships	• properties such as flammability, etc. – persistence – irreversibility – ubiquity – delayed effects – potency for harm • dose-response relationships
2 Exposure/vulnerability assessment	Modelling diffusion, exposure and effects on risk targets	• exposure pathways • normalised behaviour of target • vulnerability of target
3 Risk estimation	• *Quantitative*: probability distribution of adverse effects • *Qualitative*: combination of hazard, exposure, and qualitative factors (scenario construction)	• expected risk value(s) (individual, collective) • xx% confidence interval • risk description • risk modelling as function of variations in context variables and parameters

estimated. If, for example, exposure can be prevented, it may not be necessary to perform any sophisticated hazard estimate.

Generic Challenges for Risk Assessment

Risk assessment is confronted with three major challenges that can be best described using the terms 'complexity', 'uncertainty' and 'ambiguity'. These three challenges are not related to the intrinsic characteristics of hazards or risks themselves but to the *state and quality of knowledge available* about both hazards and risks. Since risks are mental constructs, the quality of their explanatory power depends on the accuracy and validity of their (real) predictions. Unlike some other scientific constructs, validating the results of risk assessments is particularly difficult because, in theory, one would need to wait indefinitely to prove that the probabilities assigned to a specific outcome were correctly assessed. If the number of predicted events is frequent and the causal chain obvious (as is the case with car accidents), validation is relatively simple and straightforward. If, however, the assessment focuses on risks where cause-effect relationships are difficult to discern, where effects are rare and/or difficult to interpret, and where variations in both causes and effects are obscuring

the results, the validation of the assessment results becomes a major problem. In such instances, assessment procedures are needed to characterise the existing knowledge with respect to complexity, remaining uncertainties and ambiguities (WBGU 2000, 195ff.; Klinke and Renn 2002).

- **Complexity** refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects. The nature of this difficulty may be traced back to interactive effects among these agents (synergism and antagonisms), long delay periods between cause and effect, inter-individual variation, intervening variables, and others. Risk assessors have to make judgements about the level of complexity that they are able to process and about how to treat intervening variables (such as lifestyle, other environmental factors, psychosomatic impacts, etc.). Complexity is particularly pertinent in the phase of estimation with respect to hazards as well as risks. Examples of highly complex risk include sophisticated chemical facilities, synergistic effects of potentially toxic substances, failure risk of large interconnected infrastructures and risks of critical loads to sensitive ecosystems.
- **Uncertainty** is different from complexity but often results from an incomplete or inadequate reduction of complexity in modelling cause-effect chains. Whether the world is inherently uncertain is a philosophical question that we will not pursue here. It is essential to acknowledge in the context of risk assessment that human knowledge is always incomplete and selective and thus contingent on uncertain assumptions, assertions and predictions (Functowicz and Ravetz 1992; Laudan 1996; Bruijn and ten Heuvelhof 1999). It is obvious that the modelled probability distributions within a numerical relational system can only represent an approximation of the empirical relational system with which to understand and predict uncertain events (Cooke 1991). It therefore seems prudent to include other, additional, aspects of uncertainty (Morgan and Henrion 1990; van Asselt 2000: 93–138; van der Sluijs et al. 2003). Although there is no consensus in the literature on the best means of disaggregating uncertainties, the following categories appear to be an appropriate means of distinguishing the key components of uncertainty:
  - *target variability* (based on different vulnerability of targets);
  - *systematic and random error in modelling* (based on extrapolations from animals to humans or from large doses to small doses, statistical inferential applications, etc.);
  - *indeterminacy or genuine stochastic effects* (variation of effects due to random events, in special cases congruent with statistical handling of random errors);
  - *system boundaries* (uncertainties stemming from restricted models and the need for focusing on a limited amount of variables and parameters);
  - *ignorance or non-knowledge* (uncertainties derived from lack or absence of knowledge).

  The first two components of uncertainty qualify as epistemic uncertainty and therefore can be reduced by improving the existing knowledge and by advancing

the present modelling tools. The last three components are genuine uncertainty components of aleatory nature and thus can be characterised to some extent using scientific approaches but cannot be further resolved. If uncertainty, in particular the aleatory components, plays a large role then the estimation of risk becomes fuzzy. The validity of the end results is questionable and, for risk management purposes, additional information is needed such as a subjective confidence level in the risk estimates, potential alternative pathways of cause-effect relationships, ranges of reasonable estimates, loss scenarios and others. Examples for high uncertainty, particularly aleatory uncertainty, include many natural disasters such as earthquakes, possible health effects of mass pollutants below the threshold of statistical significance, acts of violence such as terrorism and sabotage and long-term effects of introducing genetically modified species into the natural environment.

- (Interpretative and normative) ambiguity is the last term in this context. Whereas uncertainty refers to a lack of clarity over the scientific or technical basis for decision-making (interpretative and normative) ambiguity is a result of divergent or contested perspectives on the justification, severity or wider 'meanings' associated with a given threat (Stirling 2003). The term 'ambiguity' may be misleading because it has different connotations in everyday English language.[9] In relation to risk governance it is understood as 'giving rise to several meaningful and legitimate interpretations of accepted risk assessments results'. It can be divided into **interpretative ambiguity** (different interpretations of an identical assessment result: e.g. as an adverse or non-adverse effect) and *normative ambiguity* (different concepts of what can be regarded as tolerable referring e.g. to ethics, quality of life parameters, distribution of risks and benefits, etc.). A condition of ambiguity emerges where the problem lies in agreeing on the appropriate values, priorities, assumptions, or boundaries to be applied to the definition of possible outcomes. What does it mean, for example, if neuronal activities in the human brain are intensified when subjects are exposed to electromagnetic radiation? Can this be interpreted as an adverse effect or is it just a bodily response without any health implication? Many scientific disputes in the fields of risk assessment and management do not refer to differences in methodology, measurements or dose-response functions, but to the question of what all of this means for human health and environmental protection. High complexity and uncertainty favour the emergence of ambiguity, but there are also quite a few simple and highly probable risks that can cause controversy and thus ambiguity. Examples for high interpretative ambiguity include low dose radiation (ionising and non-ionising), low concentrations of genotoxic substances, food supplements and hormone treatment of cattle. Normative ambiguities can be associated, for example, with pass-

[9] With respect to risk and decision-making the term ambiguity has been used with various meanings. Some analysts refer to ambiguity as the conflicting goals of participants in the process (Skinner 1999), others use the term ambiguity when they refer to the inability to estimate probabilities of an event occurring (Gosh and Ray 1997: Ho et al. 2002; Stirling 2003). In the context of the present framework ambiguity denotes the variability in interpretation and normative implications with respect to accepted evidence.

ive smoking, nuclear power, pre-natal genetic screening and genetically modified food.

Risk Perception

Since risk is a mental construct there are a wide variety of construction principles for conceptualising risk. Different disciplines within the natural and social sciences have formed their own concepts of risk; stakeholder groups, driven by interest and experience, have developed their specific perspective on risk; and, last but not least, representatives of civil society as well as the general public are responding to risks according to their own risk constructs and images. These images are called '**perceptions**' in the psychological and social sciences and they have been intensely researched in relation to risk – as have their underlying factors (Covello 1983; Slovic 1987; Boholm 1998; Rohrmann and Renn 2000). Risk perceptions belong to the contextual aspects that risk managers need to consider when deciding whether or not a risk should be taken as well as when designing risk reduction measures.

First of all it is highly important to know that human behaviour is primarily driven by perception and not by facts or by what is understood as facts by risk analysts and scientists. Most cognitive psychologists believe that perceptions are formed by common sense reasoning, personal experience, social communication and cultural traditions (Brehmer 1987; Drottz-Sjöberg 1991; Pidgeon et al. 1992; Pidgeon 1998). In relation to risk it has been shown that humans link certain expectations, ideas, hopes, fears and emotions with activities or events that have uncertain consequences. People do, however, not use completely irrational strategies to assess information, but, most of the time, follow relatively consistent patterns of creating images of risks and evaluating them. These patterns are related to certain evolutionary bases of coping with dangerous situations. Faced with an eminent threat, humans react with four basic strategies: *flight*, *fight*, *play dead* and, if appropriate, *experimentation* (on the basis of trial and error).

In the course of cultural evolution the basic patterns of perception were increasingly enriched with cultural patterns. These cultural patterns can be described by so-called *qualitative evaluation characteristics* (Slovic 1992). They describe properties of risks or risky situations going beyond the two classical factors of risk assessment based on which risk is usually judged, i.e. level of probability and degree of possible harm. Here, psychologists differentiate between two classes of qualitative perception patterns: on the one hand *risk-related patterns*, which are based on the properties of the source of risk; on the other hand *situation-related patterns*, based on the idiosyncrasies of the risky situation (Fischhoff et al. 1978; Slovic 1987, 1992).

One example of a risk-related pattern is the perceived 'dread' of the consequences of a possible harmful event. If, for example, a person is riding in a car and thinking about possible accidents, s/he will always be under the impression s/he would, with high probability, get away unscathed in a car accident ('fender-bender

mentality'). However, if the same person is sitting in an airplane s/he will be under the impression that if something happens here there is no getting away. This feeling of apprehensiveness does not subside even when this person knows the odds and is convinced that statistically many more people die in car accidents than in airplane crashes.

Situation-related patterns of perception include aspects such as voluntariness and the ability to exercise self-control. If a person is of the opinion that s/he can control the risk, then s/he will perceive it as less serious. This mode of thinking frequently takes effect where eating habits are concerned. People believe they can easily do without sweets, alcohol or other food considered unhealthy, if only they wanted to. However, mostly harmless chemical food additives are perceived as a threat to one's health. With respect to collective risks, people show special concern for risks that they believe are not adequately controlled by public authorities (as in the case of GMOs).

Considered together these qualitative evaluation characteristics can be subdivided into a limited number of consistent risk perception classes. In literature they are also called **semantic risk patterns**. The following patterns were examined particularly thoroughly (Renn 2004a):

- risks posing an immediate threat such as nuclear energy or large dams;
- risks dealt with as a twist of fate such as natural disasters;
- risks presenting a challenge to one's own strength such as sports activities;
- risk as a gamble such as lotteries, stock exchanges, insurances;
- risks as an early indication of insidious danger such as food additives, ionising radiation, viruses.

These patterns have functions similar to drawers in a filing cabinet. When faced with a new risk or when obtaining new information about a risk, most people try to file this new information into one of the existing drawers.[10] In addition to the cognitive processing of risk characteristics and risk situations, studies have shown that people tend to *stigmatise risk sources* that are associated with specific dreadful associations (Kunreuther and Heal 2003). A salient example of stigma is the reaction to products that are deemed to be carcinogenic, although there is often limited, if any, scientific evidence to support this position. The mere suspicion that a substance could cause cancer is often sufficient for generating fear and asking for strict regulatory actions. Stigmatisation leads to a cycle of public outrage and regulatory responses feeding into the process that has been described as social amplification of risk (Kasperson et al. 1988, 2003). Stimulated by media reporting, the public's perception of the risk is often amplified in ways that are difficult to explain if one were focusing on the standard elements of any technical risk assessment – probability and direct losses.

The problems associated with risk perception are compounded because of the difficulty individuals have in interpreting low probabilities when making their decisions (Kunreuther et al. 2001). In fact, there is evidence that people may not even

[10] The 'drawers' cannot be treated in detail here since this would exceed the scope of this document (more information in Streffer et al. 2003: 269ff.).

want data on the likelihood of an event occurring. If people do not think probabilistically, how do they make their choices? Psychological research has revealed the following patterns of drawing inferences about probabilities and risks (Tversky and Kahneman 1974; Ross 1977; Kahneman and Tversky 1979; Renn 2004a):

- The easier and faster a risk is recognised, the more conscious individuals are of it and the greater is the chance of its probability being overestimated. If, for example, an individual has known someone who died after being struck by lightning, that individual will perceive the risk of being struck by lightning as being particularly large (*availability bias*).
- The more a risk provokes associations with known events, the more likely its probability will be overestimated. This is why, for example, the use of the term 'incinerating' in waste disposal facilities readily evokes an association with harmful chemicals, especially dioxins and furans, even if there is no way that they could be released into the environment by the facilities concerned (*anchoring effect*).
- The more constant and similar the losses from risk sources, the more likely the impact of average losses will be underestimated. While road traffic accidents are not deemed acceptable, they are more or less passively accepted. If the average annual number of road deaths in a given country were to occur at one point in time instead of being spread out over the year, then a considerably greater level of rejection could be expected. Thus, people are not indifferent as regards the *distribution of risks over time*: they prefer even loss distribution over individual disasters (Kahneman and Tversky 1979).
- The greater the uncertainty of loss expectation, the more likely the average loss assessment will be in the region of the median of all known loss expectations. In this way, loss expectations in objectively low risks are often overestimated while objectively high risks are often underestimated (*assessment bias*).

While important for actually evaluating and managing a risk, overestimation or underestimation of loss expectations is not, however, the most important aspect of risk perception. Instead the context-dependent nature of risk assessment is the deciding factor. This context includes the qualitative risk evaluation characteristics, the semantic images and the stigma effects. More recently, psychologists have also discovered that affect and emotions play an important role in people's decision processes (Slovic et al. 2002; Loewenstein et al. 2001). These factors are particularly relevant when individuals face a decision that involves a difficult trade-off between attributes or where there is interpretative ambiguity as to what constitutes a 'right' answer. In these cases, people often appear to resolve problems by focusing on those cues that send the strongest affective signals (Hsee and Kunreuther 2000).

The most important policy question is how to treat risk perceptions in a policy arena that includes responses of different actors and the general public (Slovic et al. 1982; Fischhoff 1985, 1995). There are two suggestions, from opposite ends of a spectrum. The first position states that the scientific concepts of risk are the only ones that can claim inter-subjective validity and applicability and, therefore, requires risk managers to obtain an assurance that (erroneous) risk perceptions are corrected

via risk communication and education (Cross 1998; Coglianese 1999). The second position states that there is no overarching universally applicable quality criterion available in order to evaluate the appropriateness or validity of risk concepts. As a result, scientific concepts (often called *narratives* in this school of thought) should compete with concepts of stakeholders and public groups (Liberatore and Funtowicz 2003). If collective decisions on risk are necessary, the concept that is used to make these decisions should be negotiated among all relevant concept holders. None of these groups, including the science communities, is allowed to claim any privileged position in this negotiation.

IRGC has strong reservations with respect to both positions. IRGC advocates an approach by which the elements of what matters to the different groups when they conceptualise risk should be regarded as equally legitimate factors for inclusion within risk governance (see also Gigerenzer and Selten 2001). This implies, for example, that if people are willing to accept higher risks when they are in control of them, then this preference cannot be de-legitimised by professional economists who favour cost-effectiveness studies that treat all risks equally. In identifying aspects of concern and worry all groups in society have the same right to raise them and to bring them to the negotiation table. However, the question of the degree to which these concerns are met or violated by risk-bearing activities or events should be primarily answered by those who have the knowledge, skills and/or the experience to measure or estimate the strength of relationships between cause (or dose) and effect. It seems wrong to give equal standing to those who intuitively estimate risks and those who assess risks on the basis of systematic observation, empirical data collection and rigorous modelling, just as it seems wrong to dismiss non-factual perceptions purely because they appear irrational to those with expert knowledge. This said, IRGC wishes to emphasise that the proposed quality distinction between intuition and systematic knowledge does not predetermine a position in the philosophical debate on realism versus constructivism; the argument here is strictly focused on the structure and content of knowledge claims, not on claims about reality representation.[11]

This position has major impacts on risk policy making and communication. Policy making needs to, inter alia, organise systematic feedback from society and, equally, to include risk perceptions as an important input to deciding on whether something should be done about a certain risk and, if so, what (Jaeger et al. 2001). How this can be accomplished is explained in the next section on risk appraisal. Risk communication is also affected, in two ways: first, it is bound to elicit, and enable the exchange of, concerns and conceptual aspects of risk among and between all relevant actors, and, second, risk managers are well advised to ensure that the best available knowledge is widely distributed to those who raise these concerns.

[11] For more comprehensive arguments on this debate see footnote 4.

Risk Appraisal

The term *risk appraisal* has sometimes been used in the risk governance literature to include all knowledge elements necessary for risk characterisation and evaluation as well as risk management (Stirling 1998, 2003). For society to make prudent choices about risks, it is not enough to consider only the results of (scientific) risk assessment. In order to understand the concerns of the various stakeholders and public groups, information about both risk perceptions and the further implications of the direct consequences of a risk – including its social mobilisation potential (i.e. how likely is it that the activity will give rise to social opposition or protest?) – is needed and should be collected by risk management agents. In addition, other aspects of the risk causing activity that seem to be relevant for characterising and evaluating the risk and selecting risk reduction options should be pulled together and fed into the analysis. Based on such a wide range of information, risk managers can make more informed judgements and design the appropriate risk management options (Clark 2001).

Risk appraisal thus includes the scientific assessment of the risks to human health and the environment and an assessment of related concerns as well as social and economic implications. The appraisal process is and should be clearly dominated by scientific analyses – but, in contrast to the traditional risk governance model, the scientific process includes both the natural/technical as well as the social sciences, including economics. We envision risk appraisal as having two process stages: first, natural and technical scientists use their skills to produce the best estimate of the physical harm that a risk source may induce (as described in the chapter on risk assessment); secondly, social scientists and economists identify and analyse the issues that individuals or society as a whole link with a certain risk. For this purpose the repertoire of the social sciences such as survey methods, focus groups, econometric analysis, macro-economic modelling, or structured hearings with stakeholders may be used.

Based on the results of risk assessment and the identification of individual and social concerns this second process stage also investigates and calculates the *social and economic implications of risks*. Of particular interest in this context are financial and legal implications, i.e. economic losses and liabilities, as well as social responses such as political mobilisation. These secondary implications have been addressed by the concept of *social amplification of risk* (Kasperson et al. 2001, 2003). This concept is based on the hypothesis 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 human health or the environment, including significant indirect impacts such as liability, insurance costs, loss of confidence in institutions, or alienation from community affairs (Burns et al. 1993). Such amplified secondary effects can then trigger demands for additional institutional responses and protective actions, or, conversely (in the case of risk attenuation), place impediments in the path of needed protective actions. Secondary

impacts, whether amplified or not, are of major concern to those who are obliged to take over the costs or cope with the consequences of being accountable.

Risk appraisal intends to produce the best possible scientific estimate of the physical, economic and social consequences of a risk source. It should not be confused with direct stakeholder involvement which will be covered later. Involvement by stakeholders and the population is only desirable at this stage if knowledge from these sources is needed to improve the quality of the assessments.

In a recent draft document published by the UK Treasury Department (2004) the authors recommend a risk appraisal procedure that includes the results of risk assessment, the direct input from data on public perception and the assessment of social concerns. The document offers a tool for evaluating public concerns using six factors related to the hazard(s) leading to a risk, the risk's effects and its management:[12]

- perception of familiarity and experience with the hazard;
- understanding the nature of the hazard and its potential impacts;
- repercussions of the risk's effects on equity (inter-generational, intra-generational, social);
- perception of fear and dread in relation to a risk's effect;
- perception of personal or institutional control over the management of a risk;
- degree of trust in risk management organisations.

A similar list of appraisal indicators was suggested by a group of Dutch researchers and the Dutch Environmental Protection Agency (van der Sluijs et al. 2003, 2004). In the late 1990s, the German Council for Global Environmental Change (WBGU) has also addressed the issue of risk appraisal and developed a set of eight criteria to characterise risks beyond the established assessment criteria (WBGU 2000). These are:

- *Extent of damage*: Adverse effects in natural units, e.g. death, injury, production loss, etc.
- *Probability of occurrence*: Estimate of relative frequency, which can be discrete or continuous.
- *Incertitude*: How do we take account of uncertainty in knowledge, in modelling of complex systems or in predictability in assessing a risk?
- *Ubiquity*: Geographical dispersion of damage.
- *Persistence*: How long will the damage last?
- *Reversibility*: Can the damage be reversed?
- *Delay effects*: Latency between initial event and actual damage.
- *Potential for mobilisation*: The broad social impact. Will the risk generate social conflict or outrage, etc.?

After the WBGU proposal had been reviewed and discussed by many experts and risk managers, it was suggested to unfold the compact 'mobilisation index' and divide it into four major elements:

[12] Since the document has only been released in late 2004, reports about practical experiences regarding its implementation are not yet available.

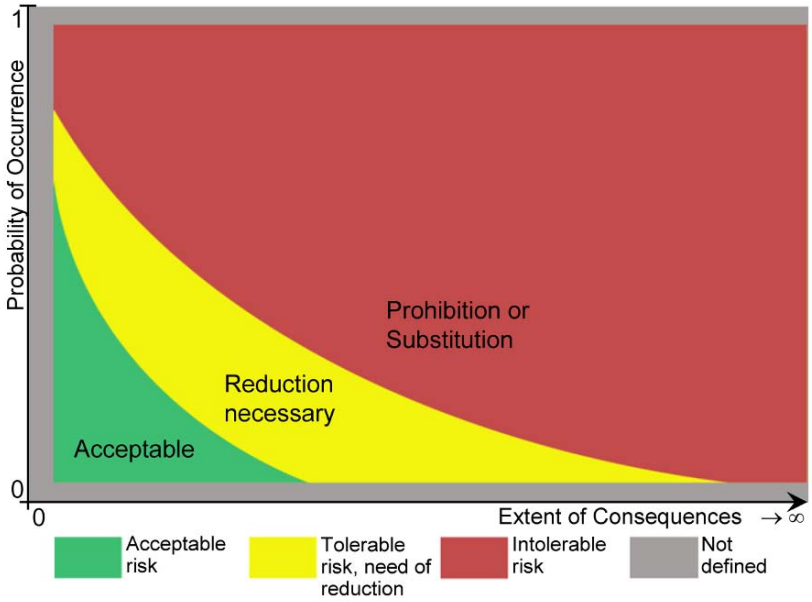

Fig. 2 Acceptable, tolerable and intolerable risks (traffic light model).

- *Inequity and injustice* associated with the distribution of risks and benefits over time, space and social status.
- *Psychological stress and discomfort* associated with the risk or the risk source (as measured by psychometric scales).
- *Potential for social conflict and mobilisation* (degree of political or public pressure on risk regulatory agencies).
- *Spill-over effects* that are likely to be expected when highly symbolic losses have repercussions on other fields such as financial markets or loss of credibility in management institutions.

These four sub-criteria reflect many factors that have been proven to influence risk perception as stated above.[13]

When dealing with complex, uncertain and/or ambiguous risks it is essential to complement data on physical consequences with data on secondary impacts, including social responses to risk, and insights into risk perception. The suggestions listed above can provide some orientation for the criteria to be considered. Depending on the risk under investigation, additional criteria can be included or proposed criteria neglected.

[13] A similar decomposition has been proposed by the UK government (Environment Agency 1998; Pollard et al. 2000).

Characterising and Evaluating Risks

The most controversial part of handling risks refers to the process of delineating and justifying a judgement about the tolerability or acceptability of a given risk (HSE 2001). The term '**tolerable**' refers to an activity that is seen as worth pursuing (for the benefit it carries) yet it requires additional efforts for risk reduction within reasonable limits. The term '**acceptable**' refers to an activity where the remaining risks are so low that additional efforts for risk reduction are not seen as necessary. For purely natural hazards the two terms appear at first glance to be meaningless, since humans have no choice in tolerating or accepting these risks. Human activities, however, do influence the impact of natural hazards through changes in vulnerability and exposure options (such as building codes or zoning laws). Looking into the resulting risks as a function of vulnerabilities, a judgement on tolerability and acceptability with respect to the selection of protective measures becomes meaningful again. The distinction between tolerability and acceptability can thus be applied to a large array of risk sources. If tolerability and acceptability are located in a risk diagram (with probabilities on the y-axis and extent of consequences on the x-axis), the well-known traffic light model emerges[14] (Figure 2). In this variant of the model the red zone signifies intolerable risk, the yellow one indicates tolerable risk in need of further management actions (in accordance with the 'as low as reasonably possible' – ALARP – principle) and the green zone shows acceptable or even negligible risk.

To draw the line between 'intolerable' and 'tolerable' as well as 'tolerable' and 'acceptable' is one of the most difficult tasks of risk governance. The UK Health and Safety Executive has developed a procedure for chemical risks based on risk-risk comparisons (Löfstedt 1997). Some Swiss cantons such as Basle County experimented with Round Tables as a means to reach consensus on drawing the two lines, whereby participants in the Round Table represented industry, administrators, county officials, environmentalists, and neighbourhood groups (RISKO 2000). Irrespective of the selected means to support this task, the judgement on acceptability or tolerability is contingent on making use of a variety of different knowledge sources. One needs to include the risk estimates derived from the risk assessment stage, and additional assessment data from the concern assessment within the appraisal stage.

Existing taxonomies of risk differ considerably in where they position the decision-making with regard to what is acceptable and what is tolerable within the overall risk process. Some assign it to the risk assessment part, others to the risk management part and others place it at the level of policy and option assessment, reaching far beyond the narrow risk acceptance criteria. For the generic approach to risk handling that this document pursues, the question of appropriate placement should be handled in a flexible manner.

[14] The traffic light model in this context is an illustrative means of mapping risks according to their tolerability or acceptability. The same metaphor has also been used to map the degree of controversy or normative ambiguity, for example in the area of siting mobile base stations (Kemp 1998; Kemp and Greulich 2004). The criticism that has been raised against using the traffic light model for addressing opposition to base stations is not relevant to the application of this model in the context of risk characterisation and evaluation.

Why? As with the framing part, judgements on acceptability rely on two major inputs: *values and evidence*. What society is supposed to tolerate or accept can never be derived from looking at the evidence alone. Likewise, evidence is essential if we are to know whether a value has been violated or not (or to what degree). With respect to values and evidence we can distinguish three cases: (i) ambiguity on evidence but not on values (interpretative ambiguity) (ii) ambiguity on values but not on evidence (normative ambiguity) and (iii) ambiguities on values and evidence.

Case 1: Interpretative ambiguity. In those cases where there is unanimous agreement about the underlying values and even the threshold of what is regarded as tolerable or acceptable, evidence in the form of risk estimates may be sufficient to locate the risk within the traffic light diagram. A judgement can then best be made by those who have most expertise in risk and concern assessments, in which case it makes sense to place this task within the domain of risk appraisal. The judgement will thus be based on best scientific modelling of epistemic uncertainties and the best qualitative characterisation of aleatory uncertainties. Characterisation also includes an analysis of the concerns associated with different outcomes and the likely secondary implications. It will be helpful for risk managers to receive best expert advice on potentially effective risk reduction measures and other management options that may lead to satisfactory results. It is, however, not the task of the risk appraisal team to make a selection of options, let alone decide on which option should be implemented.

Leaving the resolution of interpretative ambiguity to the risk and concern assessors places a major challenge to the science-based assessment process. It may be extremely difficult for experts to find an agreement on interpreting ambiguous results. It is not uncommon for the public to hear expert 1 say that there is 'nothing to worry about regarding a particular risk' while at the same time learning from expert 2 that 'this risk should be on your radar screen'. One way to capture these discrepancies in risk interpretations is to construct an *exceedance probability (EP) curve* (Grossi and Kunreuther 2005). An EP curve specifies the probabilities that certain level of losses will be exceeded. The losses can be measured in terms of dollars of damage, fatalities, illness or some other unit of analysis.

To illustrate with a specific example, suppose one was interested in constructing an EP curve for dollar losses to homes in Seattle from an earthquake. Using probabilistic risk assessment, one combines the set of events that could produce a given dollar loss and then determines the resulting probabilities of exceeding losses of different magnitudes. Based on these estimates, one can construct the mean EP depicted in Figure 3. By its nature, the EP curve inherently incorporates uncertainty associated with the probability of an event occurring and the magnitude of dollar losses. This uncertainty is reflected in the 5% and 95% confidence interval curves in the figure.

The EP curve also serves as an important tool for evaluating risk management options, thus assisting managers to optimise risk reduction. It puts pressure on experts to state the assumptions on which they are basing their estimates of the likelihood of certain events occurring and the resulting consequences. In fact, EP curves, such as those depicted in Figure 3, supplemented by a discussion of the nature of these

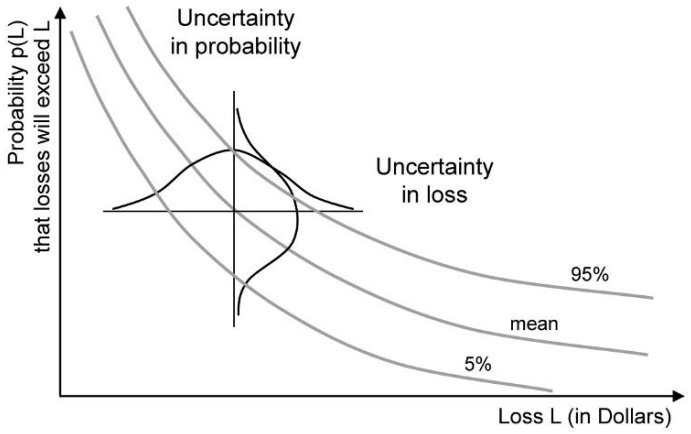

Fig. 3 Example of loss exceedance probability curves.

assumptions, should enable the assessors to both characterise interpretative ambiguities and to provide a framework for risk managers to test the efficiency of risk reduction options.

Case 2: Normative ambiguity. If the underlying values of what could be interpreted as tolerable or acceptable are disputed, while the evidence of what is at stake is clearly given and non-controversial, the judgement needs to be based on a discourse about values and their implications. Such a discourse falls clearly in the domain of risk management. A good example may be the normative implications of risks related to smoking. Science is very familiar with these risks and there is little uncertainty and interpretative ambiguity about dose-effect relationships. Yet there is considerable debate whether smoking is tolerable or not. Being a voluntary activity some countries leave it to the decision of each consumer while others initiate major activities to reduce and even ban smoking. Another example is wearing helmets on bicycles. The statistical data on this subject is rather straightforward; there are no major uncertainties or interpretative ambiguities. Yet many countries do dot want to impinge on the freedom of each cyclist to personally decide whether or not to wear a helmet, while other countries pursue a more paternalistic policy.

Case 3: Interpretative and normative ambiguity. A third case arises where both the evidence and the values are disputed. This would imply that assessors should engage in an activity to find some common ground for characterising and qualifying the evidence and risk managers need to establish agreement about the appropriate values and their application. A good example for this third case may be the interpretative and normative implications of global climate change. An international expert group such as the Intergovernmental Panel on Climate Change (IPCC) has gone through considerable effort to articulate a common characterisation of climatic risks and their uncertainties. Given the remaining uncertainties and the complexities of the causal relationships between greenhouse gases and climate change, it is then a

question of values whether governments place their priorities on prevention or on mitigation (Keeney and McDaniels 2001).

Since the third of the above cases includes both of the other two, the process of judging the tolerability and acceptability of a risk can be structured into two distinct components: risk characterisation and risk evaluation. The first step, '**risk characterisation**', determines the evidence-based component for making the necessary judgement on the tolerability and/or acceptability of a risk; the step '**risk evaluation**' determines the value-based component for making this judgement. Risk characterisation includes tasks such as point estimates of risks, descriptions of remaining uncertainties (as undertaken for instance in climate change models or risk studies on endocrine disruptors) and potential outcome scenarios including the social and economic implications, suggestions for safety factors to include inter-target variation, assurance of compatibility with legal prescriptions, risk-risk comparisons, risk-risk trade-offs, identification of discrepancies between risk assessment and risk perceptions as well as of potential equity violations, and suggestions for reasonable standards to meet legal requirements (Stern and Fineberg 1996). The evidence collected and summarised here goes beyond the classic natural science reservoir of knowledge and includes economic and social science expertise. This is also the reason why in the process of risk characterisation an interdisciplinary team of scientists is needed to draw a complete picture of what is known and what is and may remain unknown. In the course of risk characterisation, scientists are asked to design a multi-criteria profile of the risk in question, make a judgement about the seriousness of the risk and suggest potential options to deal with the risk.

The second step, risk evaluation, broadens the picture to include pre-risk aspects such as choice of technology, social need for the specific risk agent (substitution possible?), risk-benefit balances, political priorities, potential for conflict resolution and social mobilisation potential. The main objective here is to arrive at a judgement on tolerability and acceptability based on balancing pros and cons, testing potential impacts on quality of life, discussing different development options for the economy and society and weighing the competing arguments and evidence claims in a balanced manner. It should be noted that this elaborate procedure is only necessary if tolerability and/or acceptability is disputed and if society faces major dissents and conflicts among important stakeholders. If so, the direct involvement of stakeholders and the public will be a prerequisite for successful risk governance.

The separation of evidence and values underlying the distinction between characterisation and evaluation is, of course, functional and not necessarily organisational. Since risk characterisation and evaluation are closely linked and each depends on the other, it may even be wise to perform these two steps simultaneously in a joint effort by both assessors and risk managers. As some analysts have pointed out (Löfstedt and Vogel 2001; Vogel 2003): the US regulatory system tends to favour an organisational combination of characterisation and evaluation, while European risk managers tend to maintain the organisational separation (particularly in the food area). IRGC takes no stance in this question: there are good reasons for both models, yet IRGC does insist on a functional distinction.

The distinction between the three challenges of risk assessment, i.e. complexity, uncertainty and ambiguity, can also assist assessors and managers in assigning, or dividing, the judgement task. If a given risk is characterised by high complexity, low remaining uncertainties and hardly any ambiguities (except for interpretative differences over an established scientific risk assessment result), it is wise to let the assessment team dominate the process of making tolerability/acceptability judgements. If, in contrast, the risk is characterised by major unresolved uncertainties and if the results lead to highly diverse interpretations of what they mean for society, it is advisable to let risk managers take the lead.

Table 4 summarises these two steps which, as we have indicated, can be closely interrelated and may be merged if the circumstances require it. The list of indicators again represents only a small selection of potential dimensions and is displayed here for illustrative purposes.

Risk Management

Risk management starts with a review of all relevant information, in particular that from the combined risk appraisal, consisting of both a risk assessment and concern assessment whereby the latter is based on risk perception studies, economic impact assessments and the scientific characterisation of social responses to the risk source. This information, together with the judgements made in the phase of risk characterisation and evaluation, form the input material on which risk management options are being assessed, evaluated and selected. At the outset, risk management is presented with three potential outcomes:

- *Intolerable situation*: this means that either the risk source (such as a technology or a chemical) needs to be abandoned or replaced or, in cases where that is not possible (for example natural hazards), vulnerabilities need to be reduced and exposure restricted.
- *Tolerable situation*: this means that the risks need to be reduced or handled in some other way within the limits of reasonable resource investments (ALARP, including best practice). This can be done by private actors (such as corporate risk managers) or public actors (such as regulatory agencies) or both (public-private partnerships).
- *Acceptable situation*: this means that the risks are so small – perhaps even regarded as negligible – that any risk reduction effort is unnecessary. However, risk sharing via insurance and/or further risk reduction on a voluntary basis present options for action which can be worthwhile pursuing even in the case of an acceptable risk.

With regard to these outcomes risk managers may either face a situation of unanimity, i.e. all relevant actors agree with how a given risk situation should be qualified, or a situation of conflict in which major actors challenge the classification under-

Table 4 Tolerability/acceptability judgement.

Assessment Components	**Definition**	**Indicators**
1 Risk characterisation	Collecting and summarising all relevant evidence necessary for making an informed choice on tolerability or acceptability of the risk in question and suggesting potential options for dealing with the risk from a scientific perspective	
	(a) risk profile	• risk estimates • confidence intervals • uncertainty measures • hazard characteristics • range of 'legitimate' interpretations • risk perceptions • social and economic implications
	(b) judging the seriousness of risk	• compatibility with legal requirements • risk-risk trade-offs • effects on equity • public acceptance
	(c) conclusions and risk reduction options	suggestions for: • tolerable risk levels • acceptable risk levels • options for handling risks
2 Risk evaluation	Applying societal values and norms to the judgement on tolerability and acceptability and, consequently, determining the need for risk reduction measures	• choice of technology • potential for substitution • risk-benefit comparison • political priorities • compensation potential • conflict management • potential for social mobilisation

taken by others. The degree of controversy is one of the drivers for selecting the appropriate instruments for risk prevention or risk reduction.

For a systematic analysis of the risk management process it is advisable to focus on tolerable risks and those where tolerability is disputed, for the other cases are fairly easy to deal with. In the case of intolerable risks – and often in the case of tolerable but highly disputed risks – risk managers should opt for prevention strategies as a means to replace the hazardous activity with another activity leading to identical and similar benefits. One should first make sure, however, that the replacement does not introduce more risks or more uncertainties than the agent that it replaces (Graham and Wiener, 1995; Wiener 1998). In the case of acceptable risks it should be left to private actors to initiate additional risk reduction or to seek insur-

ance for covering potential but acceptable losses (although this does not eliminate the need for all concerned to have sufficient information and resources to do so). If risks are classified as tolerable, or if there is dispute as to whether they are tolerable or acceptable, risk management needs to design and implement actions that make these risks acceptable over time. Should this not be feasible then risk management, aided by communication, needs at least to credibly convey the message that major effort is undertaken to bring these risks closer to being acceptable. This task can be described in terms of classic decision theory, i.e. in the following steps (Morgan 1990; Keeney 1992; Hammond et al. 1999):

(a) *Identification and generation of risk management options*: Generic risk management options include risk avoidance, risk reduction, risk transfer and – also an option to take into account – self retention. Whereas to avoid a risk means either selecting a path which does not touch on the risk (e.g. by abandoning the development of a specific technology) or taking action in order to fully eliminate a certain risk, risk transfer deals with ways of passing the risk on to a third party. Self retention as a management option essentially means taking an informed decision to do nothing about the risk and to take full responsibility both for the decision and any consequences occurring thereafter. Risk management by means of risk reduction can be accomplished by many different means. Among them are:

- technical standards and limits that prescribe the permissible threshold of concentrations, emissions, take-up or other measures of exposure;
- performance standards for technological and chemical processes such as minimum temperatures in waste incinerators;
- technical prescriptions referring to the blockage of exposure (e.g. via protective clothing) or the improvement of resilience (e.g. immunisation or earthquake tolerant construction);
- governmental economic incentives including taxation, duties, subsidies and certification schemes;
- third party incentives, i.e. private monetary or in kind incentives;
- compensation schemes (monetary or in kind);
- insurance and liability;
- co-operative and informative options ranging from voluntary agreements to labelling and education programmes.

All these options can be used individually or in combination to accomplish even more effective risk reduction. Options for risk reduction can be initiated by private and public actors or both together.

(b) *Assessment of risk management options with respect to predefined criteria*: Each of the options will have desired and unintended consequences which relate to the risks that they are supposed to reduce. In most instances, an assessment should be done according to the following criteria:

- *Effectiveness*: Does the option achieve the desired effect?

- *Efficiency*: Does the option achieve the desired effect with the least resource consumption?
- *Minimisation of external side effects*: Does the option infringe on other valuable goods, benefits or services such as competitiveness, public health, environmental quality, social cohesion, etc.? Does it impair the efficiency and acceptance of the governance system itself?
- *Sustainability*: Does the option contribute to the overall goal of sustainability? Does it assist in sustaining vital ecological functions, economic prosperity and social cohesion?
- *Fairness*: Does the option burden the subjects of regulation in a fair and equitable manner?
- *Political and legal implementability*: Is the option compatible with legal requirements and political programmes?
- *Ethical acceptability*: Is the option morally acceptable?
- *Public acceptance*: Will the option be accepted by those individuals who are affected by it? Are there cultural preferences or symbolic connotations that have a strong influence on how the risks are perceived?

Measuring management options against these criteria may create conflicting messages and results. Many measures that prove to be effective may turn out to be inefficient or unfair to those who will be burdened. Other measures may be sustainable but not accepted by the public or important stakeholders. These problems are aggravated when dealing with global risks. What appears to be efficient in one country may not work at all in another country. Risk managers are therefore well advised to make use of the many excellent guidance documents on how to handle risk trade-offs and how to employ decision analytic tools for dealing with conflicting evidence and values (cf. Viscusi 1994; Wiener 1998; van der Sluijs et al. 2003; Goodwin and Wright 2004).

(c) *Evaluation of risk management options*: Similar to risk evaluation, this step integrates the evidence on how the options perform with regard to the evaluation criteria with a value judgement about the relative weight each criterion should be assigned. Ideally, the evidence should come from experts and the relative weights from politically legitimate decision makers. In practical risk management, the evaluation of options is done in close cooperation between experts and decision makers. As pointed out later, this is the step in which direct stakeholder involvement and public participation is particularly important and is therefore best assured by making use of a variety methods (Rowe and Frewer 2000; OECD 2002).

(d) *Selection of risk management options*: Once the different options are evaluated, a decision has to be made as to which options are selected and which rejected. This decision is obvious if one or more options turn out to be dominant (relatively better on all criteria). Otherwise, trade-offs have to be made that need legitimisation (Graham and Wiener 1995). A legitimate decision can be made on the basis of formal balancing tools (such as cost-benefit or multi-criteria-decision

analysis), by the respective decision makers (given his decision is informed by a holistic view of the problem) or in conjunction with participatory procedures.

(e) *Implementation of risk management options*: It is the task of risk management to oversee and control the implementation process. In many instances implementation is delegated, as when governments take decisions but leave their implementation to other public or private bodies or to the general public. However, the risk management team has at any rate the implicit mandate to supervise the implementation process or at least monitor its outcome.

(f) *Monitoring of option performance*: The last step refers to the systematic observation of the effects of the options once they are implemented. The monitoring system should be designed to assess intended as well as unintended consequences. Often a formal policy assessment study is issued in order to explore the consequences of a given set of risk management measures on different dimensions of what humans value. In addition to generating feedback for the effectiveness of the options taken to reduce the risks, the monitoring phase should also provide new information on early warning signals for both new risks and old risks viewed from a new perspective. It is advisable to have the institutions performing the risk and concern assessments participate in monitoring and supervision so that their analytic skills and experience can be utilised in evaluating the performance of the selected management options.

These steps follow a logical sequence but can be arranged in different orders depending on both situation and circumstance. It might be helpful to visualise the steps not as a linear progression but as a circle forming an iterative process in which reassessment phases are intertwined with new options emerging, new crisis situations arising or new demands being placed on risk managers. Similarly, sometimes the assessment of different options causes the need for new options to be created in order to achieve the desired results. In other cases, the monitoring of existing rules impacts on the decision to add new criteria to the portfolio. Rarely do issues for risk appraisal and management thus follow the sequence used for the description of the process in this paper. Option generation, information processing, and options selection should indeed be seen as a dynamic process with many iterative loops.

Table 5 summarises the steps of risk management in accordance with the basic model used by decision theory. The list of indicators represents the most frequently used heuristic rules for selecting input and for measuring performance.

Risk Management Strategies

Based on the distinction between complexity, uncertainty, and ambiguity it is possible to design generic strategies of risk management to be applied to classes of risks, thus simplifying the risk management process as outlined above. One can distinguish four such classes:

Table 5 Generic components of risk management.

Management Components	**Definition**	**Indicators**
1 Option generation	Identification of potential risk handling options, in particular risk reduction, i.e. prevention, adaptation and mitigation, as well as risk avoidance, transfer and retention	• standards • performance rules • restrictions on exposure or vulnerability • economic incentives • compensation • insurance and liability • voluntary agreements • labels • information/education
2 Option assessment	Investigations of impacts of each option (economic, technical, social, political, cultural)	• effectiveness • efficiency • minimisation of side effects • sustainability • fairness • legal and political implementability • ethical acceptability • public acceptance
3 Option evaluation and selection	Evaluation of options (multi-criteria analysis)	• assignment of trade-offs • incorporation of stakeholders and the public
4 Option implementation	Realisation of the most preferred option	• accountability • consistency • effectiveness
5 Monitoring and feedback	• Observation of effects of implementation (link to early warning) • Ex-post evaluation	• intended impacts • non-intended impacts • policy impacts

- **Simple risk problems**: This class of risk problems requires hardly any deviation from traditional decision-making. Data is provided by statistical analysis, goals are determined by law or statutory requirements and the role of risk management is to ensure that all risk reduction measures are implemented and enforced. Traditional risk-risk comparisons (or risk-risk trade-offs), risk-benefit analysis and cost-effectiveness studies are the instruments of choice for finding the most appropriate risk reduction measures. Additionally, risk managers can rely on best practice and, in cases of low impact, on trial and error. It should be noted, however, that simple risks should not be equated with small or negligible risks. The major issues here are that the potential negative consequences are

obvious, the values that are applied are non-controversial and the remaining uncertainties low. Examples are car accidents, known food and health risks, regularly reoccurring natural disasters or safety devices for high buildings.

- **Complex risk problems**: For this risk class major input for risk management is provided by the scientific characterisation of the risk. Complex risk problems are often associated with major scientific dissent about complex dose-effect relationships or the alleged effectiveness of measures to decrease vulnerabilities (for complexity refers to both the risk agent and its causal connections and the risk absorbing system and its vulnerabilities). The objective for resolving complexity is to receive a complete and balanced set of risk and concern assessment results that fall within the legitimate range of plural truth claims.

  In a situation where there is no complete data the major challenge is to define the factual base for making risk management or risk regulatory decisions. So the main emphasis is on improving the reliability and validity of the results that are produced in the risk appraisal phase. Risk and concern assessors as well as managers need to make sure that all relevant knowledge claims are selected, processed and evaluated. They may not get a single answer but they might be able to get a better overview on the issues of scientific controversy. If these efforts lead to an acknowledgement of wide margins of uncertainty, the management tools of the uncertainty strategy should be applied. If input variables to decision-making can be properly defined and affirmed, risk characterisation and evaluation can be done on the basis of risk-benefit balancing and normative standard setting (*risk-based/risk-informed regulation*). Traditional methods such as risk-risk-comparison, cost-effectiveness and cost-benefit analysis are also well-suited to facilitate the overall judgement for placing the risk in the traffic-light model (acceptable, tolerable or intolerable). These instruments, if properly used, provide effective, efficient and fair solutions with respect to finding the best trade-off between opportunities and risks. The choice of instruments includes all the classic options outlined in the section on risk management.

  It is, however, prudent to *distinguish management strategies for handling the risk agent* (such as a chemical or a technology) *from those needed for the risk absorbing system* (such as a building, an organism or an ecosystem). Addressing complex structures of risk agents requires methods for improving causal modelling and data quality control. With respect to risk absorbing systems the emphasis is on the improvement of *robustness*[15] in responding to whatever the target is going to be exposed to. Measures to improve robustness include inserting conservatisms or safety factors as an assurance against individual variation (normally a factor of 10-100 for occupational risk exposure and 100–1000 for public risk exposure), introducing redundant and diverse safety

[15] The terms robustness and resilience have different meanings in different contexts. In most of the *natural hazard literature*, robustness is one of the main components of resilience. In much of the *cybernetic literature*, robustness refers to the insensitivity of numerical results to small changes, while resilience characterises the insensitivity of the entire system against surprises. Our suggestion for distinguishing the two comes close to the cybernetic use of the terms.

devices to improve structures against multiple stress situations, reducing the susceptibility of the target organism (example: iodine tablets for radiation protection), establishing building codes and zoning laws to protect against natural hazards as well as improving the organisational capability to initiate, enforce, monitor and revise management actions (high reliability, learning organisations).

- **Risk problems due to high unresolved uncertainty**: If there is a high degree of remaining uncertainties, risk management needs to incorporate hazard criteria (which are comparatively easy to determine), including aspects such as reversibility, persistence, and ubiquity, and select management options empowering society to deal even with worst case scenarios (such as containment of hazardous activities, close monitoring of risk-bearing activities, securing reversibility of decisions in case risks turn out to be higher than expected). According to IRGC, the management of risks characterised by multiple and high uncertainties should be guided by the *precautionary approach*. Since high unresolved uncertainty implies that the (true) dimensions of the risks are not (yet) known, one should pursue a cautious strategy that allows learning by restricted errors. The main management philosophy for this risk class is to allow small steps in implementation (containment approach) that enable risk managers to stop or even reverse the process as new knowledge is produced or the negative side effects become visible. The primary thrust of precaution is to avoid irreversibility (Klinke and Renn 2002).[16]

  With respect to risk absorbing systems, the main objective is to make these systems resilient so they can withstand or even tolerate surprises. In contrast to robustness, where potential threats are known in advance and the absorbing system needs to be prepared to face these threats, *resilience* is a protective strategy against unknown or highly uncertain hazards. Instruments for resilience include the strengthening of the immune system, diversification of the means for approaching identical or similar ends, reduction of the overall catastrophic potential or vulnerability even in the absence of a concrete threat, design of systems with flexible response options and the improvement of conditions for emergency management and system adaptation. Robustness and resilience are closely linked but they are not identical and require partially different types of actions and instruments.

- **Risk problems due to interpretative and normative ambiguity**: If risk information is interpreted differently by different stakeholders in society – i.e. there are different viewpoints about the relevance, meaning and implications of factual explanations and predictions for deciding about the tolerability of a risk as well as management actions – and if the values and priorities of what should be protected or reduced are subject to intense controversy, risk management needs to address the causes for these conflicting views (von Winterfeldt and

[16] The link between precaution and irreversibility was also mentioned in the aforementioned latest report on risk management by the UK Treasury Department (2004).

Edwards 1984).

Genetically modified organisms for agricultural purposes may serve as an example to illustrate the intricacies related to ambiguity. Surveys on the subject demonstrate that people associate high risks with the application of gene technology for social and moral reasons (Hampel and Renn 2000). Whether the benefits to the economy balance the costs to society in terms of increased health risks, was not mentioned as a major concern of the polled public. Instead, people disagreed about the social need for genetically modified food in western economies where abundance of conventional food is prevalent. They were worried about the loss of personal capacity to act when selecting and preparing food, about the long-term impacts of industrialised agriculture and the moral implications of tampering with nature (Sjöberg 1999). These concerns cannot be addressed by either scientific risk assessments or by determining the right balance between over- and under-protection. The risk issues in this debate focus on the differences between visions of the future, basic values and convictions, and the degree of confidence in the human ability to control and direct its own technological destiny. These wider concerns require the inclusion within the risk management process of those who express or represent them.

Risk managers should thus initiate a broader societal discourse to enable participative decision making. These discursive measures are aimed at finding appropriate conflict resolution mechanisms capable of reducing the ambiguity to a manageable number of options that can be further assessed and evaluated. The main effort of risk management is hence the organisation of a suitable discourse combined with the assurance that all stakeholders and public groups can question and critique the framing of the issue as well as each element of the entire risk chain.

Table 6 provides a summary of these four risk strategies and lists the instruments and tools that are most appropriate for the respective strategy. Again it should be emphasised that the list of strategies and instruments is not exhaustive and can be amended if the case requires it.

Managing Interdependencies

In an interdependent world, the risks faced by any individual, company, region or country depend not only on its own choices but also on those of others. Nor do these entities always face one risk at a time: they may need to find strategies to deal with a series of interrelated risks that are often ill-defined or outside of their control. In the context of terrorism, the risks faced by any given airline, for example, are affected by lax security at other carriers or airports. There are myriad settings that demonstrate similar interdependencies, including many problems in computer and network security, corporate governance, investment in research, and vaccination. Because interdependence does not require proximity, the antecedents to catastrophes can be

Table 6 Risk characteristics and their implications for risk management.

Knowledge Characterisation	**Management Strategy**	**Appropriate Instruments**	**Stakeholder Participation**
1 'Simple' risk problems	*Routine-based*: (tolerability/acceptability judgement)	→ Applying 'traditional' decision- making • Risk-benefit analysis • Risk-risk trade-offs	Instrumental discourse
	(risk reduction)	• Trial and error • Technical standards • Economic incentives • Education, labelling, information • Voluntary agreements	
2 Complexity-induced risk problems	*Risk-informed*: (risk agent and causal chain)	→ Characterising the available evidence • Expert consensus seeking tools: – Delphi or consensus conferencing – Meta analysis – Scenario construction, etc. • Results fed into routine operation	Epistemological discourse
	Robustness-focused: (risk absorbing system)	→ Improving buffer capacity of risk target through: • Additional safety factors • Redundancy and diversity in designing safety devices • Improving coping capacity • Establishing high reliability organisations	
3 Uncertainty-induced risk problems	*Precaution-based*: (risk agent)	→ Using hazard characteristics such as persistence, ubiquity etc. as proxies for risk estimates. Tools include: • Containment • ALARA (as low as reasonably achievable) and ALARP (as low as reasonably possible) • BACT (best available control technology), etc.	Reflective discourse
	Resilience-focused: (risk absorbing system)	→ Improving capability to cope with surprises • Diversity of means to accomplish desired benefits • Avoiding high vulnerability • Allowing for flexible responses • Preparedness for adaptation	
4 Ambiguity-induced risk problems	*Discourse-based*:	→ Application of conflict resolution methods for reaching consensus or tolerance for risk evaluation results and management option selection • Integration of stakeholder involvement in reaching closure • Emphasis on communication and social discourse	Participative discourse

quite distinct and distant from the actual disaster, as was the case of the September 11, 2001 attacks when security failures at Boston's Logan Airport led to crashes at the World Trade Center (WTC), the Pentagon, and in rural Pennsylvania. The same was true in the case of the August 2003 power failures in the Northeastern US and Canada, where the initiating event occurred in Ohio, but the worst consequences were felt hundreds of miles away. Similarly, a disease in one region can readily spread to other regions with which it has contact, as was the case with the rapid spread of SARS from China to its trading partners.

The more interdependencies there are within a particular setting (be this a set of organisational units, companies, a geographical area or a number of countries, etc.) and the more that this setting's entities – or participants – decide not to invest in risk reduction while being able to contaminate other entities, the less incentive each potentially affected participant will have to invest in protection. At the same time, however, each participant would have been better off had all the other participants invested in risk-reducing measures. In other words, weak links may lead to suboptimal behaviour by everyone.[17]

For situations in which participants are reluctant to adopt protective measures to reduce the chances of catastrophic losses due to the possibility of contamination from weak links in the system, a solution might be found in a public-private partnership. This is particularly true if the risks to be dealt with are associated with competing interpretations (ambiguities) as to what type of co-operation is required between different epistemic communities as well as risk management agencies in order to deal with various knowledge and competing value claims. Public-private partnerships also provide an interesting alternative in cases in which perceptions differ strongly and external effects are to be expected.

One way to structure such a partnership is to have government standards and regulations coupled with third party inspections and insurance to enforce these measures. Such a management-based regulatory strategy will not only encourage the addressees of the regulation, often the corporate sector, to reduce their risks from e.g. accidents and disasters. Indeed, it equally shifts the locus of decision-making from the government regulatory authority to private companies which are as a result required to do their own planning as to how they will meet a set of standards or regulations (Coglianese and Lazer 2003). This, in turn, can enable companies to choose those means and measures which are most fit for purpose within their specific environment and, eventually, may lead to a superior allocation of resources compared to more top-down forms of regulation. The combination of third party inspections in conjunction with private insurance is consequently a powerful combination of public oversight and market mechanisms that can convince many companies of the advantages of implementing the necessary measures to make their plants safer and encourage the remaining ones to comply with the regulation to avoid being caught and prosecuted.

Highly interdependent risks that can lead to stochastic contamination of third parties pose a specific challenge for global risk management (i.e. the management

[17] A more formal game theoretic treatment of this problem has been published in Kunreuther and Heal (2003).

of transboundary, international and ubiquitous risks). Due to the often particularly decentralised nature of decision-making in this area, a well balanced mix of consensual (e.g. international agreements and standards, gentleman's agreements), coercive (e.g. government regulation) and incentive-based (e.g. emission certificates) strategies is necessary to deal with such risk problems. Again these strategies can be best developed in close – international and transnational – cooperation between the public and the private sector. To generate the background knowledge for such cooperation and to facilitate its realisation is one of the prime goals of IRGC.

Stakeholder Involvement and Participation

Our emphasis on governance rather than governments or administrations is meant to underline the importance that IRGC places on the inclusion of stakeholders and public groups within the risk handling process and, consequently, on the establishment of adequate public-private partnerships and participatory processes. In the context of this framework we define **stakeholders** as socially organised groups that are or will be affected by the outcome of the event or the activity from which the risk originates and/or by the risk management options taken to counter the risk. Involving stakeholders is not enough, however. Other groups, including the media, cultural elites and opinion leaders, the non-organised *affected* public and the non-organised *observing* public, all have a role to play in risk governance.

Each decision-making process has two major aspects: what and whom to include on the one hand and what and how to select (closure) on the other hand (Hajer and Wagenaar 2003; Stirling 2004). *Inclusion and selection* are therefore the two essential parts of any decision or policy making activity. Classic decision analysis has been offering formal methods for generating options and evaluating these options against a set of predefined criteria. With the advent of new participatory methods, the two issues of inclusion and selection have become more complex and sophisticated than purported in these conventional methods.

The present framework advocates the notion of inclusive governance, in particular with respect to global and systemic risks. First and foremost this means that the four major actors in risk decision making, i.e. *political*, *business*, *scientific* and *civil society players*, should jointly engage in the process of framing the problem, generating options, evaluating options, and coming to a joint conclusion. This has also been the main recommendation of the EU White Paper on European Governance (EU 2001a). This document endorses transparency and accountability through formal consultation with multiple actors as a means for the European Union to address the various frames of governance issues and to identify culture-sensitive responses to common challenges and problems. Similarly to the actors determining the governance of a political union, it is obvious that the actors participating in risk-related decision-making are guided by particular interests which derive not only from the fact that some of them are risk producers – whereas others are exposed to it – but, equally, from their individual institutional rationale and perspective. Such

vested interests require specific consideration and measures so that they are made transparent and, if possible, can be reconciled. Inclusive governance, as it relates to the inclusion part of decision-making, requires that (Trustnet 1999; Webler 1999; Wynne 2002):

- there has been a major attempt to involve representatives of all four actor groups (if appropriate);
- there has been a major attempt to empower all actors to participate actively and constructively in the discourse;
- there has been a major attempt to co-design the framing of the (risk) problem or the issue in a dialogue with these different groups;
- there has been a major attempt to generate a common understanding of the magnitude of the risk (based on expertise of all participants) as well as the potential risk management options and to include a plurality of options that represent the different interests and values of all parties involved;
- there has been a major effort to conduct a forum for decision-making that provides equal and fair opportunities for all parties to voice their opinion and to express their preferences; and
- there has been a clear connection between the participatory bodies of decision-making and the political implementation level.

If these conditions are met, evidence shows that actors, along with developing faith in their own competence, use the opportunity and start to place trust in each other and have confidence in the process of risk management (Kasperson et al. 1999; Viklund 2002; Beierle and Cayford 2002: 30f.). This is particularly true for the local level where the participants are familiar with each other and have more immediate access to the issue (Petts 1997). Reaching consensus and building trust on highly complex and controversial subjects such as global change is, however, much more difficult. Being inclusive and open to social groups does not guarantee, therefore, constructive cooperation by those who are invited to participate. Some actors may reject the framing of the issue and choose to withdraw. Others may benefit from the collapse of an inclusive governance process. It is essential to monitor these processes and make sure that particular interests do not dominate the deliberations and that rules can be established and jointly approved to prevent destructive strategising.

Inclusive governance needs to address the second part of the decision-making process as well, i.e. reaching closure on a set of options that are selected for further consideration, while others are rejected. Closure does not mean to have the final word on a development, a risk reduction plan or a regulation. Rather, it represents the product of a deliberation, i.e. the agreement that the participants reached. The problem is that the more actors, viewpoints, interests and values are included and thus represented in an arena, the more difficult it is to reach either a consensus or some other kind of joint agreement. A second set of criteria is thus needed, to evaluate the process by which closure of debates (be they final or temporary) is brought forth as well as the quality of the decision or recommendation that is generated through the closure procedure.

The first aspect, the quality of the closure process itself, can be subdivided into the following dimensions (Webler 1995; Wisdon and Willis 2004):

- Have all arguments been properly treated? Have all truth claims been fairly and accurately tested against commonly agreed standards of validation?
- Has all the relevant evidence, in accordance with the actual state-of-the-art knowledge, been collected and processed?
- Was systematic, experiential and practical knowledge and expertise adequately included and processed?
- Were all interests and values considered and was there a major effort to come up with fair and balanced solutions?
- Were all normative judgements made explicit and thoroughly explained? Were normative statements derived from accepted ethical principles or legally prescribed norms?
- Were all efforts undertaken to preserve plurality of lifestyles and individual freedom and to restrict the realm of collectively binding decisions to those areas in which binding rules and norms are essential and necessary to produce the wanted outcome?

Turning to the issues of outcome, additional criteria need to be addressed. They have been discussed in the political science and governance literature for a long time (Dryzek 1994; Rhodes 1997). They are usually stated as comprising effectiveness, efficiency, accountability, legitimacy, fairness, transparency, acceptance by the public and ethical acceptability. They largely coincide with those that have been postulated earlier for the assessments of risk management options.

When contemplating the requirements for inclusion, closure process and outcome quality, IRGC is convinced that:

- more inclusive procedures enrich the generation of options and perspectives, and are therefore more responsive to the complexity, uncertainty and ambiguity of the risk phenomena which are being assessed;
- more rational closure processes provide fairer and socially and culturally more adaptive and balanced judgements;
- the combination of voluntary and regulatory actions in form of public-private partnerships can be improved through early and constructive involvement procedures; and
- the outcomes derived from these procedures are of higher quality in terms of effectiveness, efficiency, legitimacy, fairness, transparency, public acceptance and ethical acceptability than the outcomes of conventional decision-making procedures.

The potential benefits resulting from stakeholder and public involvement depend, however, on the quality of the participation process. It is not sufficient to gather all interested parties around a table and merely hope for the catharsis effect to emerge spontaneously. In particular, it is essential to treat the time and effort of the participating actors as scarce resources that need to be handled with care and respect (Chess et al. 1998). The participation process should be designed so that the various actors

are encouraged to contribute to the process in those areas in which they feel they are competent and can offer something to improve the quality of the final product.

In this respect the four risk classes discussed earlier, i.e. simple, complex, high uncertainty and high ambiguity risk problems, support generic suggestions for participation (Renn 2004b):

- *Simple risk problems*: For making judgements about simple risk problems a sophisticated approach to involve all potentially affected parties is not necessary. Most actors would not even seek to participate since the expected results are more or less obvious. In terms of cooperative strategies, an '**instrumental discourse**' among agency staff, directly affected groups (such as product or activity providers and immediately exposed individuals) as well as enforcement personnel is advisable. One should be aware, however, that often risks that appear simple turn out to be more complex, uncertain or ambiguous as originally assessed. It is therefore essential to revisit these risks regularly and monitor the outcomes carefully.

- *Complex risk problems*: The proper handling of complexity in risk appraisal and risk management requires transparency over the subjective judgements and the inclusion of knowledge elements that have shaped the parameters on both sides of the cost-benefit equation. Resolving complexity necessitates a discursive procedure during the appraisal phase with a direct link to the tolerability and acceptability judgement and risk management. Input for handling complexity could be provided by an '**epistemological discourse**' aimed at finding the best estimates for characterising the risks under consideration. This discourse should be inspired by different science camps and the participation of experts and knowledge carriers. They may come from academia, government, industry or civil society but their legitimacy to participate is their claim to bring new or additional knowledge to the negotiating table. The goal is to resolve cognitive conflicts. Exercises such as Delphi, Group Delphi and consensus workshops would be most advisable to serve the goals of an epistemological discourse (Webler et al. 1991; Gregory et al. 2001).

- *Risk problems due to high unresolved uncertainty*: Characterising risks, evaluating risks and designing options for risk reduction pose special challenges in situations of high uncertainty about the risk estimates. How can one judge the severity of a situation when the potential damage and its probability are unknown or highly uncertain? In this dilemma, risk managers are well advised to include the main stakeholders in the evaluation process and ask them to find a consensus on the extra margin of safety in which they would be willing to invest in exchange for avoiding potentially catastrophic consequences. This type of deliberation called '**reflective discourse**' relies on a collective reflection about balancing the possibilities for over- and under-protection. If too much protection is sought, innovations may be prevented or stalled; if we go for too little protection, society may experience unpleasant surprises. The classic question of 'how safe is safe enough' is replaced by the question of 'how much uncertainty and ignorance are the main actors willing to accept in exchange for

some given benefit'. It is recommended that policy makers, representatives of major stakeholder groups, and scientists take part in this type of discourse. The reflective discourse can take different forms: round tables, open space forums, negotiated rule-making exercises, mediation or mixed advisory committees including scientists and stakeholders (Amy 1983; Perrit 1986; Rowe and Frewer 2000).

- *Risk problems due to high ambiguity*: If major ambiguities are associated with a risk problem, it is not enough to demonstrate that risk regulators are open to public concerns and address the issues that many people wish them to take care of. In these cases the process of risk evaluation needs to be open to public input and new forms of deliberation. This starts with revisiting the question of proper framing. Is the issue really a risk problem or is it in fact an issue of lifestyle and future vision? The aim is to find consensus on the dimensions of ambiguity that need to be addressed in comparing risks and benefits and balancing the pros and cons. High ambiguities require the most inclusive strategy for participation since not only directly affected groups but also those indirectly affected have something to contribute to this debate. Resolving ambiguities in risk debates requires a '**participative discourse**', a platform where competing arguments, beliefs and values are openly discussed. The opportunity for resolving these conflicting expectations lies in the process of identifying common values, defining options that allow people to live their own vision of a 'good life' without compromising the vision of others, to find equitable and just distribution rules when it comes to common resources and to activate institutional means for reaching common welfare so all can reap the collective benefits instead of a few (coping with the classic commoners' dilemma).[18] Available sets of deliberative processes include citizen panels, citizen juries, consensus conferences, ombudspersons, citizen advisory commissions, and similar participatory instruments (Dienel 1989; Fiorino 1990; Durant and Joss 1995; Armour 1995; Applegate 1998).

Categorising risks according to the quality and nature of available information on risk may, of course, be contested among the stakeholders. Who decides whether a risk issue can be categorised as simple, complex, uncertain or ambiguous? It is possible that no consensus may be reached as to where to locate a specific risk. In those cases, a detailed (worst-case) analysis of possibilities of monitoring and surveillance may constitute the only achievable compromise (reversible removal of risk sources etc., timely detection of adverse effects, strength of surveillance systems). The best means, however, to deal with this conflict is to provide for stakeholder involvement when allocating the different risks into these four categories. This task can be located in the phase of screening as the third component of pre-assessment. Allocating risks to the four categories needs to be done before the assessment procedures start. Over the course of further analysis of risks and concerns the categorisation may change since new data and information is being collected that may necessitate a re-ordering of the risk. Yet the risk governance system that is proposed in this document builds

[18] For a more detailed analysis of participatory methods for reaching consensus refer to Barber (1984), Webler (1999) or Jaeger et al. (2001).

upon the need to classify risks at the beginning and allocate them to different routes of appraisal, characterisation, evaluation and management. It seems prudent to have a screening board perform this challenging task. This board should consist of members of the risk and concern assessment team, of risk managers and key stakeholders (such as industry, NGOs and representatives of related regulatory or governmental agencies). The type of discourse required for this task is called **design discourse**. It is aimed at selecting the appropriate risk and concern assessment policy, defining priorities in handling risks, organising the appropriate involvement procedures and specifying the conditions under which the further steps of the risk handling process will be conducted.

Figure 4 provides an overview of the different requirements for participation and stakeholder involvement for the four classes of risk problems and the design discourse. As is the case with all classifications, this scheme shows an extremely simplified picture of the involvement process and it has been criticised for being too rigid in its linking of risk characteristics (complexity, uncertainty, and ambiguity) and specific forms of discourse and dialogue (van Asselt 2005). In addition to the generic distinctions shown in the graph below, it may for instance be wise to distinguish between participatory processes based on risk agent or risk absorbing issues. To conclude these caveats, the purpose of this scheme is to provide general orientation and explain a generic distinction between ideal cases rather than to offer a strict recipe for participation.

Risk Communication

Given the arguments about risk perception and stakeholder involvement, IRGC believes strongly that effective communication has to be at the core of any successful activity to assess and manage risks. The field of risk communication initially developed as a means of investigating how best expert assessments could be communicated to the public so that the tension between public perceptions and expert judgement could be bridged. In the course of time this original objective of educating the public about risks has been modified and even reversed as the professional risk community realised that most members of the public refused to become 'educated' by the experts but rather insisted that alternative positions and risk management practices should be selected by the professional community in their attempt to reduce and manage the risks of modern technology (Plough and Krimsky 1987).

In a recent review of risk communication, William Leiss identified *three phases in the evolution of risk communication practices* (Leiss 1996: 85ff.). The first phase of risk communication emphasised the necessity to convey probabilistic thinking to the general public and to educate the laypersons to acknowledge and accept the risk management practices of the respective institutions. The most prominent instrument of risk communication in phase I was the application of risk comparisons. If anyone was willing to accept x fatalities as a result of voluntary activities, she or he should be obliged to accept another voluntary activity with less than x fatalities. However,

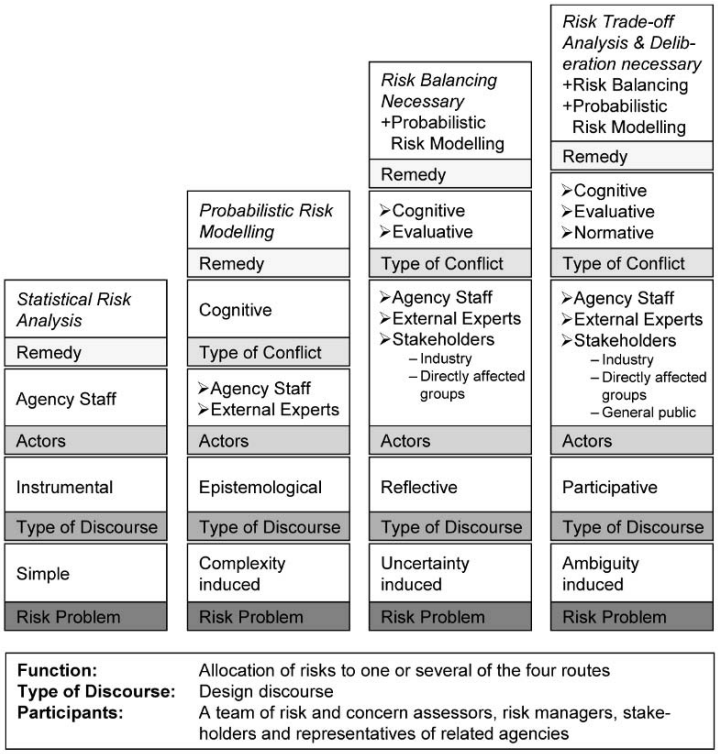

Fig. 4 The risk management escalator and stakeholder involvement (from simple via complex and uncertain to ambiguous phenomena).

this logic failed to convince audiences: people were unwilling to abstract from the context of risk-taking and the corresponding social conditions and they also rejected the reliance on expected values as the only benchmarks for evaluating risks. When this attempt at communication failed, phase II was initiated. This emphasised persuasion and focused on public relations efforts to convince people that some of their behaviour was unacceptable (such as smoking and drinking) since it exposed them to high risk levels, whereas public worries and concerns about many technological and environmental risks (such as nuclear installations, liquid gas tanks, or food additives) were regarded as overcautious due to the absence of any significant risk level. This communication process resulted in some behavioural changes at the personal level: many people started to quit some unhealthy habits. However, it did not convince a majority of these people that the current risk management practices for most of the technological facilities and environmental risks were indeed the politically appropriate response to risk. The one-way communication process of conveying a message to the public in carefully crafted, persuasive language produced little effect. Most respondents were appalled by this approach or simply did not believe the message, regardless how well it was packaged, so phase III evolved. This current

phase of risk communication stresses a two-way communication process in which not only are members of the public expected to engage in a social learning process, but so are the risk managers as well. The objective of this communication effort is to build mutual trust by responding to the concerns of the public and relevant stakeholders. The ultimate goal of risk communication is to assist stakeholders in understanding the rationale of risk assessment results and risk management decisions, and to help them arrive at a balanced judgement that reflects the factual evidence about the matter at hand in relation to their own interests and values (OECD 2002). Good practices in risk communication help stakeholders to make informed choices about matters of concern to them and to create mutual trust (Hance et al. 1988; Lundgren 1994).

Risk communication is needed throughout the whole risk handling chain, from the framing of the issue to the monitoring of risk management impacts. The precise form of communication needs to reflect the nature of the risks under consideration, their context and whether they arouse, or could arouse, societal concern. Communication has to be a means to both ensure that:

- those who are central to risk framing, risk appraisal or risk management understand what is happening, how they are to be involved, and, where appropriate, what their responsibilities are; and,
- others outside the immediate risk appraisal or risk management process are informed and engaged.

The first task of risk communication, i.e. facilitating an exchange of information among risk professionals, has often been underestimated in the literature. A close communication link between risk/concern assessors and risk managers, particularly in the phases of pre-assessment and tolerability/acceptability judgement, is crucial for improving overall governance. Similarly, co-operation among natural and social scientists, close teamwork between legal and technical staff and continuous communication between policy makers and scientists are all important prerequisites for enhancing risk management performance. This is particularly important for the initial screening phase where the allocation of risks is performed.

The second task, that of communicating risk appropriately to the outside world, is also a very challenging endeavour. Many representatives of stakeholder groups and, particularly, members of the affected and non-affected public are often unfamiliar with the approaches used to assess and manage risks and/or pursue a specific agenda, trying to achieve extensive consideration of their own viewpoints. They face difficulties when asked to differentiate between the potentially dangerous properties of a substance (hazards) and the risk estimates that depend on both the properties of the substance, the exposure to humans, and the scenario of its uses (Morgan et al. 2002). Also complicating communication is the fact that some risks are acute, with severe effects that are easy to recognise, whereas others exert adverse effects only weakly but over a long period of time. Yet other risks' effects only start to show after an initial delay. Finally, it is no easy task to convey possible synergies of exposures to industrial substances with other factors that relate to lifestyle (e.g. nutrition, smoking, use of alcohol).

Effective communication, or the non-existence thereof, has a major bearing on how well people are prepared to face and cope with risk. Limited knowledge of, and involvement in, the risk management process can lead to inappropriate behaviour in emergency or risk-bearing situations (for example, when facing a pending flood or handling contaminated food or water). There is also the risk of failed communication: consumers or product users may misread or misunderstand risk warnings or labels so that they may, through ignorance, expose themselves to a larger risk than necessary. This is particularly prevalent in countries with high rates of illiteracy and unfamiliarity with risk-related terms. Providing understandable information to help people cope with risks and disasters is, however, only one function of risk communication. Most risk communication analysts list four major functions (Morgan et al. 1992; OECD 2002):

- *Education and enlightenment*: inform the audience about risks and the handling of these risks, including risk and concern assessment and management.
- *Risk training and inducement of behavioural changes*: help people cope with risks and potential disasters.
- *Creation of confidence in institutions responsible for the assessment and management of risk*: give people the assurance that the existing risk governance structures are capable of handling risks in an effective, efficient, fair and acceptable manner (such credibility is crucial in situations in which there is a lack of personal experience and people depend on neutral and disinterested information). It should be kept in mind, however, that trust cannot be produced or generated, but only be accumulated by performance, and that it can be undermined by the lack of respect for an individual within such an institution.
- *Involvement in risk-related decisions and conflict resolution*: give stakeholders and representatives of the public the opportunity to participate in the risk appraisal and management efforts and/or be included in the resolution of conflicts about risks and appropriate risk management options.

For all four functions, risk communication needs to address the following topics:

- explain the concept of probability and stochastic effects;
- explain the difference between risk and hazard;
- deal with stigmatised risk agents or highly dreadful consequences (such as nuclear waste or cancer);
- cope with long-term effects;
- provide an understanding of synergistic effects with other lifestyle factors;
- address the problem of remaining uncertainties and ambiguities;
- cope with the diversity of stakeholders and parties in the risk appraisal and management phase;
- cope with inter-cultural differences within pluralist societies and between different nations and cultures.

Although risk communication implies a stronger role for risk professionals to provide information to the public rather than vice versa, it should be regarded as a mutual learning process in line with the requirements that Leiss postulated for

phase III. Concerns, perceptions and experiential knowledge of the targeted audience(s) should thus guide risk professionals in their selection of topics and subjects: it is not the task of the communicators to decide what people need to know but to respond to the questions of what people want to know ('right to know' concept, see Baram 1984). Risk communication requires professional performance both by risk and communication experts. Scientists, communication specialists and regulators are encouraged to take a much more prominent role in risk communication, because effective risk communication can make a strong contribution to the success of a comprehensive and responsible risk management programme. IRGC will invest much of its resources and efforts in contributing to the improvement of current risk communication practices and in itself acting as an effective risk communicator.

Wider Governance Issues: Organisational Capacity

The above framework covering the areas of risk framing (i.e. pre-assessment), appraisal (including risk assessment as well as the assessment of risk-related concerns and the non-physical secondary implications of risk), characterisation/evaluation, management and communication concludes this document's analysis of the classic components of handling risks. Looking at organisational capacity opens a new set of wider risk governance issues which relate to the interplay between the governing actors and their capability to fulfil their role in the risk governance process.

In discussing the different components of risk appraisal and management, it was implicitly assumed that society has developed the institutional and organisational capability to perform all the tasks prescribed in each component – preferably in a matter-of-fact, objective manner. This is, of course, an ideal picture that masks the realities of the *political* context in which risk governance takes place. In particular, the framing of risk is exposed to many institutional and political forces who may wish to jump on the bandwagon of public dissent or media hype in order to push their own interests (Shubik 1991). Given the potential of risk perceptions to mobilise public outrage and, thus, to make it impossible for decision-makers not to listen, some actors in society may have an interest in orchestrating 'risk events', whereas others might have a major motivation for concealing risks or downplaying their impacts. Most political systems have responded to this manoeuvring by establishing independent risk assessment and sometimes management agencies, expecting that these are less likely to be influenced by public pressures. Although IRGC is well aware of the political context in which risk governance takes place, it cannot provide guidance on how to govern risk debates. What it can and intends to do, however, is give advice on how to base risk governance on the best available knowledge and practice. Such advice addresses, first, the process phases of risk appraisal, management and communication as stated above and, second, the strengthening of institutions and agencies so that they are empowered and resourced to perform their tasks in the most effective, efficient and fair manner. As the European Commission's White Paper on European Governance pointed out, the key ingredients of 'good'

governance in this sense are openness, participation, accountability, effectiveness and coherence (EU 2001a: 10). These requirements are important for all countries but, in particular, for many transitional and most developing countries. Since the IRGC's scope includes offering assistance to these countries, its work includes criteria for how to analyse and improve organisational capacity and 'good' governance practices.

For the analysis of institutional capacity it is useful to distinguish between assets, skills and capabilities (cf. Paquet 2001). Assets form the social capital for risk governance in the form of knowledge bases and structural conditions for effective management. *Skills* refer to the quality of institutional and human performance in exploring, anticipating and dealing with existing and emerging risks. *Capabilities* describe the institutional framework necessary to translate assets and skills into successful policies. These three components constitute the backbone of institutional capacity for risk governance.

The assets include:

- *Rules, Norms, Regulations*: these establish rights and obligations. In the risk area, the existence of norms, standards, best practices, legal instruments, etc., has always been a major and often contentious issue, hence the importance of such assets. This is true not only with regard to their prescribing of how to deal with risk but also for the absence, or the lack of observance, of rules (e.g. with regard to the end use of new technologies) which itself constitutes an increasing factor of risk.
- *Resources*: these are not limited to financial resources but comprise of an appropriate physical infrastructure for managing risk as well as the availability of adequate information, including the means for information gathering and processing.
- *Competencies and Knowledge*: this involves providing the necessary education and training and establishing and maintaining a pool of experience and expertise. Education should not only be directed at specialists but should reach out to the general public, building a culture of awareness and prevention.
- *Organisational Integration*: the capacity to access and retrieve, in a combination tailored to individual cases, each of these first three types of assets. Organisational integration is a key element, without which otherwise worthy assets will struggle to achieve much.

Using an analogy from mathematics, the three first assets are additive while organisational integration is a multiplying factor. A non-existent organisational capability for integration would nullify the efficacy of the other factors.

Skills are related to the capacity of organisations and institutions to deal with evolving, sometimes chaotic, external conditions. Such conditions should not be considered as an eventuality that cannot be dealt with, but should, instead, be viewed as input parameters to the risk process that require adequate treatment. Skills should enable political, economic and civic actors to use effectively, and enhance the impact of, the available assets. They relate to:

- *Flexibility*, i.e. new ways to make sense of a dynamic situation – adapting to change, which in many cases means fighting against established practices and institutional inertia. An example to illustrate this point can be found in the current concern that city planning frequently still follows 19th century practices while the increase in magnitude and frequency of extreme climatic events associated with climate change should dictate a new approach.
- *Vision*, i.e. bringing new practices into a context that would not naturally generate them – anticipating change. This implies devoting more attention to advanced methodological approaches such as foresight and scenario planning, and a preparedness to think 'outside the box'.
- *Directivity*, i.e. reframing the whole perception of the way of life – driving change that impacts on the outside world rather than limiting oneself to preventing or mitigating the effects of external forces. Several environmental policies (e.g. ban on CFCs) and security policies (e.g. ban on Weapons of Mass Destruction) adopted at the international level reflect this approach.

Using the same mathematical analogy, the three factors constituting the skills are in an additive relationship with each other. Within that relationship they can exhibit different intensities as a function of the nature of external forces.

Capabilities, finally, constitute the framework in which assets enriched by skills can be exploited for developing and implementing successful risk governance policies. Capabilities can be conceptualised as a structure with several successive layers (Wolf 2005):

- *Relations* link users and sources of knowledge as well as those carrying the authority and those bearing the risk, notably civil society. As previously stated, the participation of civil society in risk governance is essential. Relations should thus be based on inclusive decision-making in order to alleviate, at the outset, any circumstances that generate dispute and conflict and consequently aggravate risk.
- *Networks* constitute, in terms of structures, a close co-operative structure that goes beyond relations. Halfway between self-organisation and hierarchy, networks determine close links between and among groups of principally equal actors.
- *Regimes* establish the rules of the game, the framework in which the actors should act. Both relations and networks are essential for forming and sustaining regimes.

Drawing on the mathematical analogy again, the factors constituting the capabilities are additive, each having a separate but complementary function in the overall build up of capabilities.

While each of these assets, skills and capabilities would lend itself to a more detailed discussion IRGC wishes to underline the major importance of risk education and training. In a world where 'human capital' – and in particular brainpower combined with inspiration, courage and a strong ability towards implementation – has largely become the life-blood of society's progress and prosperity, it is quite evident that one of the major keys to the successful handling of risk is in people's heads

as well. Given the often systemic and global (transboundary, international and ubiquitous) nature of today's major risks, special 'competencies and knowledge' are required. Specialised in-depth expert knowledge in a restricted area or sector may no longer suffice to understand and counteract risks which spread the boundaries of academic disciplines and business sectors, have several layers of effects and are determined by a multitude of often interlinked factors. However, compartmentalised specialisation is what many educational systems still foster. This approach should, in fact, be replaced by one which emphasises risk appraisal and management in education at all levels and which considers risk under a broad and multi-disciplinary perspective. There is a particular need for this in the engineering, architecture and design disciplines where a primarily technical focus should be extended to health, safety and environmental risk. Such a new approach, fostering in fact a 'bird's eye perspective' with regard to risk, should be anchored in national science and education policies and should grow to become part of our scientific and technological culture.

All three factors – assets, skills and capabilities – are important variables when assessing and investigating risk governance structures in different countries or risk domains; they can also serve as guiding principles for identifying and researching deficiencies and providing assistance to improve capacity. It may even be possible, based on the above mathematical analogies, to construct an overall performance indicator that could help countries to evaluate their risk governance capacities and to use these elements as pathfinders for establishing new institutional frameworks to achieve improved structures for coping with risk.

The Role of Political Culture

When considering the wider environment of risk handling in modern societies, many classes of influential factors come into play. Only a few can be mentioned here. For example, the distinction between horizontal and vertical governance as introduced in the first section of this document can be helpful in describing and analysing cases of risk handling in different countries and contexts (Zürn 2000). In addition, the interplay between economic, political, scientific and civil society actors needs to be addressed when looking beyond just governmental or corporate actions.

It is the goal of IRGC to focus particularly on risk areas which have multidimensional and transnational implications, rather than revisiting classic areas of risk regulation by individual governments or routine risk handling by private corporations. In this focus, one major aspect of risk governance concerns political culture, i.e. *regulatory regimes or governmental styles*. Each country and, in many instances, different risk domains within a country pursue different pathways for dealing with risk. The multitude of risk classification documents and meta-analyses of risk taxonomies is obvious proof of the plurality of risk handling processes and conceptual approaches. It may thus be helpful to search for some underlying principles of these approaches and classify them accordingly.

This exercise of finding common denominators in cultural and national diversity is less of a challenge than one may assume at first glance. Most analysts agree that many of the cognitive factors that govern risk perception are similar throughout the world (Rohrmann and Renn 2000). In addition, risk management styles are also becoming increasingly homogenous as the world becomes more globalised (Löfstedt and Vogel 2001). In spite of the distinct cultural differences among nations and the variations with respect to educational systems, research organisations, and structures of scientific institutions, assessment and management of risks and concerns have become universal enterprises in which nationality, cultural background or institutional setting play a minor role only. This is particularly due to the role of science in proposing and justifying regulatory standards. Research establishments as well as universities have evolved into multinational and cosmopolitan institutions that speak identical or at least similar languages and exchange ideas on world-wide communication networks.[19]

Risk management depends, however, not only on scientific input. It rather rests on three components: *systematic knowledge*, *legally prescribed procedures* and *social values*. Even if the same knowledge is processed by different risk management authorities, the prescriptions for managing risk may differ in many aspects (e.g. with regard to inclusion and selection rules, interpretative frames, action plans for dealing with evidence, and others). National culture, political traditions, and social norms furthermore influence the mechanisms and institutions for integrating knowledge and expertise in the policy arenas. Policy analysts have developed a classification of governmental styles that address these aspects and mechanisms. While these styles have been labelled inconsistently in the literature, they refer to common procedures in different settings (O'Riordan and Wynne 1987). They are summarised in Table 7.

- The **'adversarial' approach** is characterised by an open forum in which different actors compete for social and political influence in the respective policy arena. The actors in such an arena use and need scientific evidence to support their position. Policy makers pay specific attention to formal proofs of evidence because their decisions can be challenged by social groups on the basis of insufficient use or negligence of scientific knowledge. Risk management and communication is essential for risk regulation in an adversarial setting because stakeholders demand to be informed and consulted. Within this socio-political context, stakeholder involvement is mandatory.
- In the **'fiduciary' approach**, the decision-making process is confined to a group of patrons who are obliged to make the 'common good' the guiding principle of their action. Public scrutiny and involvement of the affected public are alien to this approach. The public can provide input to and arguments for the patrons but is not allowed to be part of the negotiation or policy formulation process. The system relies on producing faith in the competence and the fairness of the patrons involved in the decision-making process. Advisors are selected

[19] Indeed, this tendency towards a universal understanding of risk problems and a common language to describe risks and risk reduction measures is one of the most relevant reasons for establishing the IRGC.

Table 7 Characteristics of policy making styles.

Style	Characteristics	Risk Management
1 *Adversarial approach*	• open to professional and public scrutiny • need for scientific justification of policy selection • precise procedural rules • oriented towards producing informed decisions by plural actors	• main emphasis on mutual agreements on scientific evidence and pragmatic knowledge • integration of adversarial positions through formal rules (due process) • little emphasis on personal judgement and reflection on the side of the risk managers • stakeholder involvement essential for reaching communication objectives
2 *Fiduciary approach (patronage)*	• closed circle of 'patrons' • no public control, but public input • hardly any procedural rules • oriented towards producing faith in the system	• main emphasis on enlightenment and background knowledge through experts • strong reliance on institutional in-house 'expertise' • emphasis on demonstrating trustworthiness • communication focused on institutional performance and 'good record'
3 *Consensual approach*	• open to members of the 'club' • negotiations behind closed doors • flexible procedural rules • oriented towards producing solidarity with the club	• reputation most important attribute • strong reliance on key social actors (also non-scientific experts) • emphasis on demonstrating social consensus • communication focused on support by key actors
4 *Corporatist approach*	• open to interest groups and experts • limited public control, but high visibility • strict procedural rules outside of negotiating table • oriented towards sustaining trust to the decision-making body	• main emphasis on expert judgement and demonstrating political prudence • strong reliance on impartiality of risk information and evaluation • integration by bargaining within scientifically determined limits • communication focused on fair representation of major societal interests

according to national prestige or personal affiliations. In this political context, stakeholder involvement may even be regarded as a sign of weakness or a diffusion of personal accountability.

- The **'consensual' approach** is based on a closed circle of influential actors who negotiate behind closed doors. Social groups and scientists work together to reach a predefined goal. Controversy is not present and conflicts are reconciled on a one-to-one basis before formal negotiations take place. Risk communication in this context serves two major goals: it is supposed to reassure the public that the 'club' acts in the best interest of the public good and to convey the feeling that the relevant voices have been heard and adequately considered. Stakeholder participation is only required to the extent that the club needs further insights from the affected groups or that the composition of the club is challenged.
- The **'corporatist' approach** is similar to the consensual approach, but is far more formalised. Well-known experts are invited to join a group of carefully selected policy makers representing the major forces in society (such as the employers, the unions, the churches, the professional associations, the environmentalists). Similar to the consensual approach, risk communication is mainly addressed to the outsiders: it has the goal of creating the impression that the club is open to all 'reasonable' public demands and that it tries to find a fair compromise between public protection and innovation. Often the groups represented within the club are asked to organise their own risk management and communication programmes as a means of enhancing the credibility of the whole management process.

Although these four styles cannot be found in pure form in any country, they form the backdrop of socio-political context variables against which specific risk governance structures are formed and operated. These structures, along with the individual actors' goals and the institutional perspectives they represent, would need more specific attention and, for the time being, are difficult to classify further.

Conclusions

One of the main mandates of IRGC is to assist risk/concern assessors and managers in exploring and handling risks and to promote effective and fair approaches for improving, and enhancing the visibility of, the present risk governance processes. IRGC's aim is to offer guidance and advice on how to approach the complexities, uncertainties and ambiguities of risk issues and to promote a wider understanding of their interconnectedness, particularly in relation to newly emerging systemic risks. To this end IRGC is developing an integrative framework that takes into account scientific, physical, economic, social and cultural aspects and includes effective and appropriate engagement of stakeholders – not least to ensure that both risk appraisal and risk management strategies command the widest possible acceptance and sup-

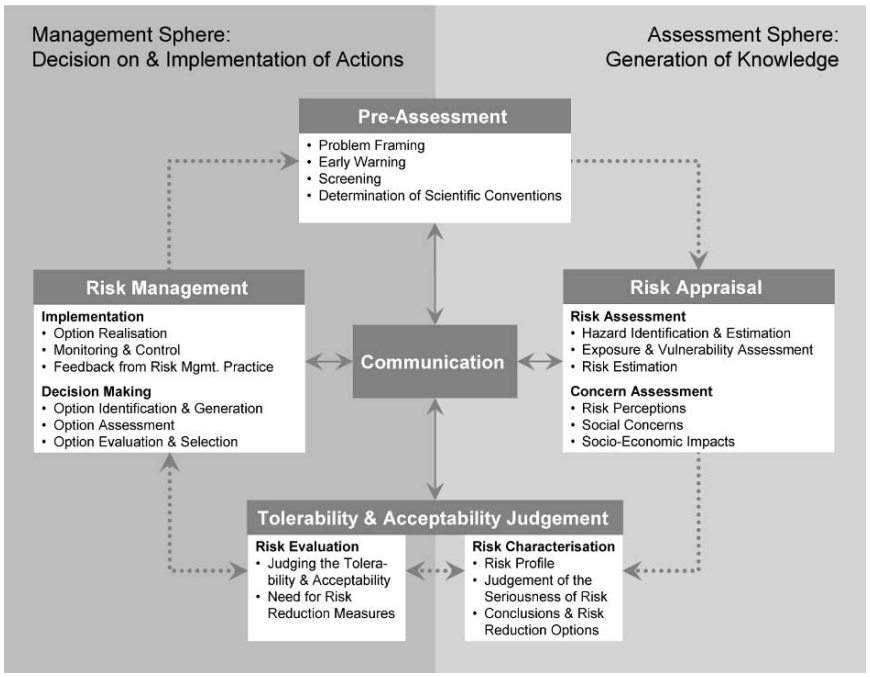

Fig. 5 IRGC Risk Governance Framework.

port. A prototype version of this framework is outlined in the present paper and summarised in Figure 5.

The framework has been designed, on one hand, to include enough flexibility to allow its users to do justice to the wide diversity of risk governance structures and, on the other hand, to provide sufficient clarity, consistency and unambiguous orientation across a range of different risk issues and countries.

This document, firstly, discussed a comprehensive risk handling chain, breaking down its various components into three main phases: 'pre-assessment', 'appraisal', and 'management'. The two intermediate and closely linked stages of risk characterisation and evaluation have been placed between the appraisal and management phases and can be assigned to either of them, depending on the circumstances: if the interpretation of evidence is the guiding principle for characterising risks, then risk and concern assessors are probably the most appropriate people to handle this task; if the interpretation of underlying values and the selection of yardsticks for judging acceptability are the key problems, then risk managers should be responsible. In an ideal setting, however, this task of determining a risk's acceptability should be performed in a joint effort by both assessors and managers. At any rate, a comprehensive, informed and value-sensitive risk management process requires a systematic compilation of results from risk assessment, risk perception studies and other context-related aspects as recommended and subsumed under the category of risk appraisal. Risk managers are thus well advised to include all the information related

to the risk appraisal in evaluating the tolerability of risks and in designing and evaluating risk reduction options. The crucial task of risk communication runs parallel to all phases of handling risk: it assures transparency, public oversight and mutual understanding of the risks and their governance.

The document, secondly, addresses wider governance issues. Its starting point has been the observation that collective decisions about risks result from an interaction between science communities, governmental or administrative actors, corporate actors and actors from civil society at large. The interplay of these actors has been discussed with reference to public participation, stakeholder involvement and governance structures (horizontal and vertical). In addition, the document highlights the need for appropriate organisational capacity as a prerequisite for effective risk governance and provides a typology of regulatory styles. These variables also co-determine the institutional structure, the processing of information and values and the quality of the outcome in terms of regulations or management options.

What lessons can be drawn for the future work of IRGC from the results of the study reported in this document? First, providing a unified yet flexible concept can assist IRGC to conduct comparative analyses among and between different risk types, thus ensuring that resource distribution on risk management across risk sources and technologies follows a consistent and efficient pattern. Second, it may help IRGC to structure its projects in line with the phases and components outlined in this report. Third, the framework may be a worthwhile basis for diagnosing deficiencies in existing risk governance regimes around the world and provide suggestions for how to improve them. Lastly, the document may serve a heuristic function by adding to the worldwide efforts for harmonising risk governance approaches and finding some common denominators for risk governance that provide a credible and substantive response to both the globalisation of the planet and the need for a coherent approach to the risks faced by our increasingly interconnected populations.

Glossary of Terms

Acceptability: Risks are deemed to be acceptable if they are insignificant and adequately controlled. There is no pressure to reduce acceptable risks further, unless cost effective measures become available. In many ways, acceptable risks are equivalent to those everyday risks which people accept in their lives and take little action to avoid. (See also 'Intolerable Risks' and 'Tolerability'.)

Agent: In the context of risk a substance, energy, human activity or psychological belief that can cause harm.

ALARA: As Low As Reasonably Achievable.

ALARP: As Low As Reasonably Practicable. (Note: There is little or no difference in practice between ALARA and ALARP. 'Reasonably practicable' is defined in some countries through case law which says that a reduction in risk is 'reasonably

practicable' unless the improvement achieved is grossly disproportionate to the cost of achieving that improvement.)

Ambiguity: Giving rise to several meaningful and legitimate interpretations of accepted risk assessments results. See also 'Interpretative Ambiguity' and 'Normative Ambiguity'. ('Ambiguity' is one of three major challenges confronting risk assessment; the others are 'complexity' and 'uncertainty'.)

Buffer Capacity: Capacity of a system to withstand a risk event (e.g. the failure of a component) through the incorporation of additional protective measures.

Complexity: Complexity refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects. ('Complexity' is one of three major challenges confronting risk assessment; the others are 'uncertainty' and 'ambiguity'.)

Coping Capacity: Building into systems, society, organisations or individuals measures to reduce the impact of a risk if it is realised. For example, measures to improve the ability of a building to resist earthquakes. (See also 'Resilience'.)

Design discourse: A form of deliberation for defining and specifying the most appropriate route for assessment and management of a given risk.

Dose-Response Relationship: The relationship between the amount of exposure (dose) to a substance (or other hazard) and the resulting changes in health or body function. (Note: Usually applied to human beings but can be applied more widely in the environment.)

Early warning: Institutional arrangement for (systematically) looking for indicators of potentially damaging events or their precursors.

Epistemological: Concerning the nature, origin and scope of knowledge. So an 'epistemological discourse' is about the scope and the quality (validity, reliability and relevance) of the information available and is aimed at finding the best estimates for characterising the risk.

Exposure: Contact of a risk target (humans, ecosystems) with a hazard.

Flexibility: One of the skills essential to tackling modern risk situations. The ability to look for new ways to make sense of a dynamic situation, if necessary to fight against traditional practices and institutional inertia, and to find novel solutions.

Framing: The initial analysis of a risk problem looking at what the major actors, e.g. governments, companies, the scientific community and the general public, select as risks and what types of problems they label as risk problems. This defines the scope of subsequent work.

Governance: At the national level, the structure and processes for collective decision making involving governmental and non-governmental actors (Nye and Donahue 2000). At the global level, governance embodies a horizontally organised structure of functional self-regulation encompassing state and non-state actors bringing about

collectively binding decision without superior authority (cf. Rosenau 1992; Wolf 2000).

Hazard: A source of potential harm or a situation with the potential to causes loss. (Australian/New Zealand risk management standard)

Horizontal Governance: This involves all the relevant actors including government, industry, NGOs and social groups in decision-making processes with a defined geographical or functional segment, such as a community or region.

Indeterminacy: See 'Stochastic Effects'.

Instrumental [discourse]: Used in the case of 'simple risks'. It is aimed at finding the most cost-effective measures to make the risk acceptable or at least tolerable.

Interpretative Ambiguity: Different interpretations of an identical assessment result: e.g. as an adverse or non-adverse effect.

Intolerable Risks (alternatively 'Unacceptable Risks'): A risk that society deems to be unacceptable, no matter what benefits arise from the activity giving rise to the risk.

Justification: The case for undertaking an activity that carries an element of risk. In effect, some kind of risk/benefit analysis which demonstrates the case for the activity.

Latency: Concealed or dormant risks; latency refers to those risks where the harm emerges some considerable time after exposure (e.g. effects of exposure to radiation).

Normative Ambiguity: Different concepts of criteria or yardsticks that help to determine what can be regarded as tolerable referring e.g. to ethics, quality of life parameters, risk-benefit balance, distribution of risks and benefits, etc.

Organisational Capacity: The ability of organisations and individuals within organisations to fulfil their role in the risk governance process.

Participative [decision making/discourse]: Open to public input; possibly including new forms of deliberation. Examples of participative discourse include citizens' juries, consensus conferences, etc.

Probabilistic Risk Assessment (PRA): Methods for calculating probability-loss functions based on statistical, experimental and/or theoretically derived data (such as event treed or fault trees). PRA is often used in the context of engineered systems.

Reflective [discourse]: Collective reflection on the course of action to take e.g. balancing possibilities of over- and under-protection in the case of large remaining uncertainties about probabilities and/or magnitude of damage(s). Examples of reflective discourse include round tables, open space forums and negotiated rule making.

Resilience: A protective strategy to build in defences to the whole system against the impact of the realisation of an unknown or highly uncertain risk. Instruments for resilience include strengthening the immune system, designing systems with flexible response options, improving emergency management, etc.

Risk: An uncertain consequence of an event or an activity with respect to something that humans value (definition originally in Kates et al. 1985: 21). Such consequences can be positive or negative, depending on the values that people associate with them.

Risk Analysis: Some organisations, e.g. Codex Alimentarius, use risk analysis as a collective term which covers risk assessment, risk management and risk communication.

Risk Appraisal: The process of bringing together all knowledge elements necessary for risk characterisation, evaluation and management. This includes not just the results of (scientific) risk assessment but also information about risk perceptions and economic and social implications of the risk consequences.

Risk Assessment: The task of identifying and exploring, preferably in quantified terms, the types, intensities and likelihood of the (normally undesired) consequences related to a risk. Risk assessment comprises hazard identification and estimation, exposure and vulnerability assessment and risk estimation.

Risk Characterisation: The process of determining the evidence based elements necessary for making judgements on the tolerability or acceptability of a risk. (See also 'Risk Evaluation'.)

Risk Estimation: The third component of risk assessment, following hazard identification and estimation, and exposure/vulnerability assessment. This can be quantitative (e.g. a probability distribution of adverse effects) or qualitative (e.g. a scenario construction).

Risk Evaluation: The process of determining the value-based components of making a judgement on risk. This includes risk-benefit balancing or incorporation of quality of life implications and may also involve looking at such issues as the potential for social mobilisation or at pre-risk issues such as choice of technology and the social need of the particular operation giving rise to the risk. (See 'Justification'.)

Risk Governance: Includes the totality of actors, rules, conventions, processes, and mechanisms concerned with how relevant risk information is collected, analysed and communicated and management decisions are taken. Encompassing the combined risk-relevant decisions and actions of both governmental and private actors, risk governance is of particular importance in, but not restricted to, situations where there is no single authority to take a binding risk management decision but where instead the nature of the risk requires the collaboration and co-ordination between a range of different stakeholders. Risk governance however not only includes a multifaceted, multiactor risk process but also calls for the consideration of contextual factors such as institutional arrangements (e.g. the regulatory and legal framework that determines the relationship, roles and responsibilities of the actors and

co-ordination mechanisms such as markets, incentives or selfimposed norms) and political culture including different perceptions of risk.

Risk Management: The creation and evaluation of options for initiating or changing human activities or (natural and artificial) structures with the objective of increasing the net benefit to human society and preventing harm to humans and what they value; and the implementation of chosen options and the monitoring of their effectiveness.

Risk Mitigation: Measures to reduce the impact of a realised risk; for example, design features in a chemical plant to direct any explosive failure in a particular direction away from sensitive parts of the plant.

Risk Perception: The outcome of the processing, assimilation and evaluation of personal experiences or information about risk by individuals or groups in society.

Risk Prevention: Measures to stop a risk being realised. This often means stopping the activity giving rise to the risk. But this, because of the need for substitution, can often give rise to other risks in the substituted activity.

Risk Reduction: Measures to reduce the level of risk, for example by reducing the likelihood of the risk being realised or reducing the impact of the risk.

Risk Screening: The process of sifting and selecting information about risk in order to allocate the risk to a particular category or to a particular control regime; the process needs to be done in a manner that avoids unnecessary compartmentalisation of a risk.

Risk Trade-Offs (or Risk-Risk Trade-Offs): The phenomenon that interventions to reduce one risk can increase other risks, or shift risk to a new population.

Risk Transfer: Passing on some or all of the consequences of a risk to a third party. In some cases, this may be part of legitimate risk management e.g. to an insurance company; in other cases, for example, where those benefiting from the risk generating activity are not those who suffer from the risk (e.g. those suffering pollution down stream from a chemical plant), risk governance needs to ensure that such transfers are dealt with fully and equitably.

Robustness: This concerns primarily the insensitivity (or resistance) of parts of systems to small changes within well defined ranges of the risk consequences (contrast with 'resilience' which more concerns whole systems).

Semantic Risk Patterns: Classes of risk that reflect certain perceptive or psychological approaches to risk. For example, one such class concerns risks posing an immediate threat such as nuclear energy; another concerns activities where an individual's perception of their vulnerability is underestimated because they believe they are 'in charge', e.g. when driving a car.

Social Amplification of Risk: An overestimation or underestimation of the seriousness of a risk caused by public concern about the risk or an activity contributing to the risk.

Social Mobilisation: Social opposition or protest that feeds into collective actions (such as voting behaviour, demonstration or other forms of public protest).

Stakeholder: Socially organised groups that are or will be affected by the outcome of the event or the activity from which the risk originates and/or by the risk management options taken to counter the risk.

Stochastic Effects: Effects due to random events.

Systemic Risk: Those risks that affect the systems on which society depends – health, transport, energy, telecommunications, etc. 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.

Taxonomy: A structure for classifying risks and approaches to methods of dealing with risks.

Tolerability: An activity that is seen as worth pursuing (for the benefit it carries) yet requires additional efforts for risk reduction within reasonable limits. (See also 'Acceptability' and 'Intolerable Risks'/ 'Unacceptable Risks'.)

Ubiquity: In the context of risk, one for which the impact of the risk being realised is widespread, usually geographically.

Unacceptable Risks: See 'Intolerable Risks'.

Uncertainty: A state of knowledge in which, although the factors influencing the issues are identified, the likelihood of any adverse effect or the effects themselves cannot be precisely described. (Note: this is different from ignorance about the effects or their likelihood. 'Uncertainty' is one of three major challenges confronting risk assessment; the others are 'complexity' and 'ambiguity'.)

Vertical Governance: This concerns the links between the various segments which may have an interest in an issue, e.g. between local, regional and state levels (whereas 'horizontal governance' concerns the links within those segments).

Vulnerability: The extent to which the target can experience harm or damage as a result of the exposure (for example, immune system of target population, vulnerable groups, structural deficiencies in buildings, etc.).

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