IRG-Project
[Integrated Risk Governance Project]

Science Plan

Integrated Risk Governance Project

International Human Dimensions Programme on Global Environmental Change

IRG-Project Science Plan
Version of March 1, 2009,
as submitted for review
to IHDP

Integrated Risk Governance Project: The Science Plan

Table of Contents

1 Executive Summary

We propose a ten-year international effort in risk research to learn how to deal with risks that exceed current coping capacities. This effort shall use key insights developed by researchers operating in the framework of IHDP, as well as in other settings. We will study risk occurrences as events in the dynamics of socio-ecological systems. In doing so, we will focus on the entry and exit transitions marking the beginning and end of emergencies.

To study these transitions, IRG-project shall develop a creative network of senior and junior researchers and practitioners in developed and developing countries. In the spirit of grounded theory, IRG-project will proceed through a sequence of comparative case studies complemented by other methods. We will start by investigating a small number of contrasting cases and stepwise add other cases as the investigation proceeds. IRG-project is conceived as a process of discoveries, and therefore will consciously create the space for surprises. The discoveries to be made shall contribute to an effective framework of integrated risk governance in view of the considerable risks humankind is facing in the 21th century.

The present science plan starts by setting out the challenge faced by risk research in view of sustainable development – a challenge that has both practical and theoretical dimensions. We then describe the research strategy with which we will tackle this challenge. The strategy combines different methods by focussing on a sequence of comparative case studies. Next, we indicate the outcomes to be produced, ranging from input into professional training and education to synergies with practical efforts at improving integrated risk governance. Finally, we delineate the implementation plan, with special emphasis on a cooperative scheme linking researchers in developing and in developed countries.

2 The Challenge

Large scale disasters, which exceed the current coping capacity of socio-ecological systems, are on the increase. Recent examples include the 2008 drought in Ethiopa and other African countries, China's great ice storm of 2008, hurricane Katrina of 2005 in the U.S., the European heatwave of 2003, as well as the global financial crisis of 2008.

During the period from 1984 through 2003, the population influenced by natural disasters exceeded 4 billion people, mostly in developing countries. The economic losses due to disasters in 1990-1999 surpassed those during the period 1950-1959 about 15 times (The World Bank 2006). Current work by the Center for Research on the Epidemiology of Disasters reveals an upward trend in the frequency of disasters over the past two decades (Scheuren et al. 2008). Damaging floods and storms in particular have increased by about 7% per year between 1988 and 2006 – they exhibit an average annual growth rate of about 8% between 2000 and 2007. Likewise, human and economic losses are on the increase. Economic losses have increased substantially from the 1960s through the 1990s (NRC 2006). In developing countries, these losses are likely to trigger serious economic damage to developing countries, in some years exceeding 3% of a country's GDP. Deaths from natural disasters are similarly concentrated in developing countries. 90% of the 880,000 estimated deaths in the 1990s, for example, occurred in developing countries (Perrow 2007).

Although these disasters differ in the ways societies responded to them or in the specific contexts in which they occurred, many of them share important commonalities. Their impacts were not confined to political boundaries, they required multi-scale, multi-actor, cross-sectoral responses, and the human, economic and environmental losses were often immense. The scale and intensity took many governance systems by surprise and challenged longstanding institutionalized solutions to disaster planning, response, management, and recovery. These losses, which show an upward trend corresponding to the frequency and intensity of large scale disasters, provide an urgent case for improving the effectiveness of our response systems. In a recent overview of the role of research in disaster management, the US National Research Council (NRC 2006) emphasized the need for systematic comparative research that examines the nature of catastrophic disasters and which sheds light on how societies improvise and innovate in their responses. While many factors contribute to any specific desaster, there is little doubt that global environmental change triggered by human activities plays a major role. In the case of climate change this has begun to raise serious concern in the insurance industry (Dlugolecki 2000).

Increasing risks are one of the most significant aspects of the human dimensions of global environmental change. Sustainable development has been defined as as a pattern of development ensuring that humankind meets the needs of the present without compromising the ability of future generations to meet their own needs. It is precisely this ability that is compromised by a growth pattern that does increase the expected value of income per capita but at the same time amplifies many risks that threaten future generations. The willingness to accept increasing risks as long as they do not materialize in the immediate present is one of the most important features of unsustainable development.

Reversing this tendency towards increasing risks is one of the most important challenges of our times. The ability – and perhaps even the willingness – to do so is quite limited, however. One reason for this is the difficulty to understand the risk dynamics. Different circumstances cannot and should not be ignored (Ostrom 2005), but they often are. Plausible explanations may deflect attention from the need for more subtle analysis, as when a focus on forces of nature puts the different possibilities to cope with them into the background (Mileti 1999). Growth of population, of income per capita, of energy use, of production of pollutants all matter, but how can the relevance of each one of these factors be assessed? And how do they relate to the economic mechanisms that enable entrepreneurs to take risks at a global scale (Shiller 2004)?

The ability to take huge risks is a precondition of the technostructure that enables humankind to communicate, travel, and trade all around the globe, and to produce unprecedented welfare by doing so. But clearly this ability has somehow gotten out of hand. As a result, a question of fairness arises with regard to the relation between present and future generations. It is a complex issue, because future generations are quite likely to be richer in monetary terms and better off in many other respects than present ones. But at the same time they are quite likely to face even larger risks than we do presently.

The lack of fairness in dealing with risk between generations is compounded by the lack of fairness within present generations. Clearly, risks to health, welfare, and safety are distributed very unevenly across humankind, and it is hard to justify this distribution by any widely recognized standards. And those parts of humankind that currently face the greatest risks also have less rosy prospects for their offspring. Clearly, there is a long way to go in order to achieve something that deserves the name of sustainable development.

The know-how on risk management that is currently available is certainly helpful to address this situation, but it is hardly sufficient. IRG-project shall contribute to further enhance that know-how as an integral component of the transition towards sustainable development.

2.1 Rationale

Shakespeare's Merchant of Venice – with his combination of risk and uncertainty, accounting and accountability, credit and interest on credit, bankrupcy and sudden fortune, greed, cruelty, and solidarity - marks the birth of professional risk management.

Modern society could not have emerged without a new fabric of financial institutions (Bernstein 1996). This fabric enables entrepreneurs to risk large losses by sharing with other agents the – positive or negative – consequences of taking these risks. This new approach to risk has evolved hand in hand with scientific knowledge about risk, provided by a wide range of disciplines, including economics, engineering, geography, mathematics, and more.

From a practical point of view, clearly insurance firms are key to the modern approach to risk. But modern insurance is impossible without credit, and banks providing credit are continuously engaged in their own process of risk assessment. Insurance firms in turn have expanded their business to an extent that they needed an insurance of their own operations, and so re-insurance has become another pillar of modern risk management.

To be able to function, today's insurance industry needs possibilities to invest huge amounts of money in ways that are profitable by themselves – because otherwise nobody would be willing to put the necessary amounts of money aside – while allowing insurers to turn their assets back into money very quickly if the need arises. These possibilities are provided by stock markets, that have become another essential component of the contemporary fabric for handling risk.

At the same time, stock markets generate risks of their own, and to handle these a wide variety of hedging operations has been developed. While hedge funds concentrate on this kind of operations, hedging is a standard procedure in many companies, be they in insurance, banking, other services, or manufacturing. Finally, the whole system of market-based risk businesses relies on government as a further stabilising factor in the face of risk. This holds for central banks, but also for various systems of social security.

From a theoretical point of view, key insights are due to the work of mathematicians. In the 17th century, two French mathematicians (Pascal and Fermat) developed a mathematical concept of probability in order to analyse various gambles. Their concept was rooted in the distinction of two finite sets: a set of equally likely possible events and a subset of favorable ones. The simplest case is a coin with the possibilities of heads and tails together with a bet that heads will obtain.

Because of its link with the notion of possibility, their concept had non-trivial philosophical ramifications (Hacking 2007). Already Aristotle had noticed that even in a finite world there is an infinity of possibilities. But if there is an infinity of equally probable possibilities, each one of them must have a probability of zero, and so what actually happens will always have zero probability. It took several generations of mathematicians to develop a concept of probability that would work well with infinite sets.

The results are the axioms of Kolmogorov, that today are the canonical way to frame mathematical probability theory. But now out of an infinite set of possible events – represented, e.g., by the real numbers between 0 and 1 – one can define a set of favorable events that is "unmeasurable", i.e. such that no probability can be obtained for a favorable event to occur. While these may seem technicalities of no interest for the practicioner, they are linked to all sorts of philosophical puzzles (Hendricks 2001). The use of mathematical probability theory has given to the practical machinery for risk management an aura of reliability, objectivity, and precision. How far this aura can be sustained in the face of both subtle theoretical problems and drastically increasing global risks, remains to be seen.

In the past decades, massive advances have been made both in risk analysis and in practical risk management. They have been synthesized by a range of scholars (Alexander 2000, Blaikie et al. 1996, Bouchaud and Potters 2000, Bunting et al. 2007, Burton et al. 1995, Haimes 2004, Jasanoff 1986, Jorion 1997, Linnerooth-Bayer et al. 2005, Morgan et al. 2002, Renn 2008, Sen and Drèze 1995) and of organizations (ICSU 2008, ISDR 2004, NRC 2006, OECD 2003, The World Bank 2006, UNDP 2004). The resulting literature provides a rich toolbox to address a large variety of risk problems.

Again and again, however, the history of risk management has been marked by the emergence of risks that exceeded the coping capacity of their times. This led to the formation first of the insurance industry, later of re-insurance. At the beginning of the 21th century, humankind as a whole again faces risks that exceed our current coping capacity. Paramount are the risks that come with nuclear weapons (Sagan 1993, Shultz et al. 2008). At the time of writing, the most urgent ones are those implied by today's global financial system (Shiller 2004).

Global environmental risks, especially those of climate change, seem to exceed current coping capaciy as well (WBGU 1998). The risks of pandemics, of asteroid impacts, of technologies like nanotechnology may well be in the same category. These risks cannot be dealt with in isolation: an ill-conceived climate policy may trigger a financial crisis that destabilizes critical regions to the point of nuclear conflict. More generally, risk management often requires the capacity to navigate a landscape shaped by a combination of major risks – a landscape known as risk society (Beck 1992, Lahsen 2007).

Risk society poses the challenge of how to establish integrated risk governance at a global scale. The challenge is most dramatic in the case of very large risks like those of nuclear weapons, global financial markets, or climate change. But it arises in the face of more regional risks as well. When in early 2008 unusual harsh weather conditions hit parts of China, they met an infrastructure that was highly vulnerable, and they did so in the very days in which millions of Chinese were travelling thousands of miles in the course of holiday visits to their relatives. Such regional risks raise major challenges in their own right. But they also convey important experiences in view of the unprecedented global risks humankind faces in the 21th century.

The practical task of integrated risk governance arises at a time when the theoretical tools of risk analysis require a serious overhaul. We have already mentioned that the use of mathematical probability theory is greatly contributing to the legitimacy of the modern fabric of risk management. And we have indicated that mathematical notions of probability arose out of the distinction between favorable and unfavorable events. For practical risk management, however, this is not sufficient. One often needs the ability to rank possibilities as being more or less favorable – as when comparing the risks of a thunderstorm with those of a hurrican. The standard mathematical tool that has been developed for this purpose is the concept of a utility function, associating a real number to each possible event. This concept has become a key element not only of risk analysis, but actually of economic theory at large.

However, a series of experimental results and theoretical findings have highlighted serious limitations in any approach to risk based on the combination of mathematical concepts of probability and utility (Machina 1987, Jaeger et al. 2001, Kahneman 2003). First, it has been shown beyond doubt that when people take decisions in real life, they do not follow that mathematical model – and this holds even for professional economists trained precisely on that model. And second, if people would try really hard to follow the model, they would waste their lives making the necessary computations without reaching any practical decision – just as chess players could not make a single move if they tried to analyse all its possible consequences.

As scholars, then, we find ourselves in a situation where institutions that have been extremely successful at dealing with risks in the past are confronted with a new dimension of risks that exceeds their coping capacity. And a key reason – although certainly not the only one – for the limitations of this coping capacity lies in the theoretical toolbox these institutions are relying on. What will be needed in order to realize a perspective of sustainable development, then, will be a combination of practical advances in integrated risk governance with theoretical advances in our understanding of risk and uncertainty. This implies a research agenda of unusual breath that will require trans-disciplinary cooperation by highly specialized researchers from very different fields. And the cooperation will need to involve a patient dialogue with practicioners faced with risks and disasters, often under a time pressure that is at odds with the rythms of creative research.

Tackling such a research agenda requires a series of steps, starting with a very limited task that can be addressed with the intellectual and institutional resources available at the beginning of the effort. For reasons that will be discussed in section 3, "Research Program", we start with a few comparative case studies on the onset of specific disasters – what we will call the entry transition in the unfolding of crises in socio-ecological systems.

2.2 Purpose

Our vision is to achieve advances in risk research by focusing on a specific phenomenon through a series of comparative case studies. The phenomenon we have chosen are the transitions in and out of the occurrence of particular risks. These transitions are of considerable relevance for practical risk management. Moreover, risk managers are particularly apt to study the complex character of the socio-ecological systems in which the risks to be investigated occur.

We will develop a research network with substantial creative potential by emphasizing work in small groups based on guided self-organization, and by consciously mixing people with very different backgrounds: senior and young researchers in both developing and developed countries, as well as selected policy makers and practitioners with an interest in innovative research.

2.3 Objectives

The mission of IRG-project is to improve the management of new risks that exceed current human coping capacities. We do so by focusing on the transitions in and out of the occurrence of relevant risks. We are convinced that there is a need for new insights in the field of risk analysis, and that these insights will include conceptual and theoretical advances. However, we have the firm intention to orient our research on the practical needs of risk management.

From a practitioner's point of view, the following four points require special attention:

1) The need to strengthen institutional capacities in the context of diagnosing the impacts of catastrophic disasters.

One example is China's recent Ice Storm in February 2008: Governmental institutions had a difficult time to understand the extent (impacts on life-lines and energy in particular), as well as the human dimension of the event (e.g. the problem of public transportation: millions of citizens wishing to use public transport to reach their homes to celebrate the commencement of the new year). The challenge in this case is to develop tools which may help government officers in charge of dealing with such disasters to dimension the potential impacts of an event in the context of various sectors, so that a more efficient and timely response is provided in such cases.

2) The need to strengthen institutional capacities to deal with collateral events which may be triggered by a main or initial event.

As a second example from China, the great Wenchuan earthquake in May 2008 triggered massive landslides which created temporary lakes that could provoke even worse disasters if they burst as a consequence of the failure of the barriers that generated them. Such an example, which has manifested itself in other regions of the world in similar cases, related to earthquakes, introduces the challenge of developing models, which can also forecast such potential collateral events.

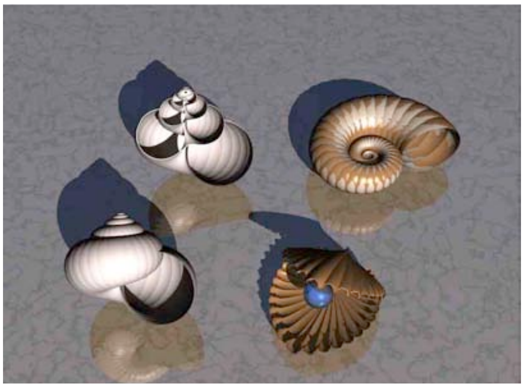
3) The need to assess as quickly as possible whether there are enough resources or not to cope with an event.

During hurricane Katrina, many people were faced with the impossibility of evacuation prior to the hurricane due to the lack of public transportation during the incident. The weakness in assessing the impacts of the event in terms of needs to evacuate people forced the government to use more costly means (evacuation by helicopters or boats) to carry out the evacuation. In this context, it is important for government agencies at all levels to assess as quickly as possible the impact of an event, and from such an impact the foreseen needs in terms of resources to respond to the event efficiently and timely. Therefore, there is a challenge to develop tools which may help government agencies in charge of responding to such disasters to assess whether there are enough resources to cope with an event as quickly as possible.

4) The need to assess the roles of agents in improving the entry and exit strategies:

In the context of the recovery processes after a disaster, it has been stated by the World Bank (2006) that in some cases, governments have requested resources to reconstruct facilities, but to the same standards which existed before the disaster to the point that vulnerabilities and risk were being recreated as before. In other disasters, one can witness that affected populations rebuild their houses again to the same degree of risk which existed before the event. Such examples exemplify the challenge of researching the key dynamic patterns of exit transitions, in order to find mechanisms which should be introduced during the recovery processes to avoid the reconstruction of risks in the public and private sectors. To this end, it is important to assess the role of agents in improving both entry and exit strategies.

2.4 Discoveries



These practical needs point to four main research questions that will be addressed within IRG-project:

1) In what respect does a given risk exceed the capacity of given coping institutions or mechanisms?

2) What aspects of entry and exit transitions foster/hinder robustness and learning with regard to the relevant risks?

3) What are the key dynamic patterns of the entry and exit transitions?

4) Who – i.e. which agents – can do what in order to improve entry and exit switches and thus risk management?

Along these four tracks, IRG-project will develop answers to the increasingly urgent overarching question: *How can risk governance be improved and synergies be created at multiple governance levels, up to the point where risks that currently leave most people profoundly helpless become challenges that can be tackled in a responsible way?*

There is simply no guarantee that a satisfactory answer can be found to this overarching question. Therefore, a sensible research strategy must involve inquiries that can be expected to contribute to it, but that promise interesting results even if the ovarching question should turn out to be elusive. For research to address a really hard question, one needs to prepare for many kinds of failures. As the saying goes, the best possible strategy is the one of Christophorus Columbus, who searched for a new way to the Indies, discovered America instead, and did not realize it.

But clearly, this cannot be an excuse for throwing research resources after ill-conceived activities and pursuing them stubbornly regardless of whatever failures one may experience. There are simple principles that can guide this kind of investigation:

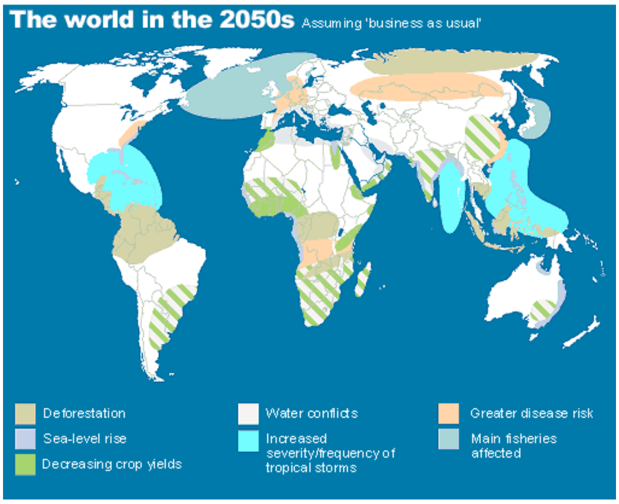
- define limited tasks that will lead to useful outcomes regardless of their contribution to the overarching question;
- operate in direct, personal contact with practitioners and use the practical issues they are faced with as signpost that help you not to get lost in the infinity of unresolved questions;
- form small teams, because large teams are good at improving existing knowledge, at applying it to new problems, but not at discovering truly novel knowledge;
- form teams combining senior with junior researchers, because discoveries are usually made by not yet established researchers, but such researchers need encouragement, training, guidance, and challenges provided by senior scholars;
- evaluate researchers more than research projects, because good researchers may be able to make significant discoveries precisely by following hints and intuitions that arise in the course of the research process;
- iterate a sequence of different methodological steps, using case studies to improve models, models to inform surveys, surveys to enrich conceptual analyses, new concepts to design better case studies;
- be patient, accepting that it may take many years until a long series of attempts yielding limited, but real successes lead to significant breakthroughs;
- combine very different skills among researchers whose personalities resonate with each other.

The last point is especially important in an endeavour like IRG-Project. Only if a culture of mutual respect and curiosity can be established amongst researchers from fields as different as civil engineering, anthropology, mathematics, management, and more, can the insights we are looking for emerge.

It may well be that a major resource of IRG-Project will be the fact that this is a truly intercultural activity, bringing together scholars from all continents in a mode of true dialogue. The history of IRG-project as a Chinese initiative, picked up first by Europeans, and then by scholars from all continents and a large variety of countries, may help the researchers involved to explore new data, methods, and concepts so as to discover truly novel insights.

When aiming at discoveries in a field as rich as the one of risk analysis and risk governance, one needs to find a terrain where empirical work and practical experience can focus the creativity of the researchers so as to achieve interesting results in a reasonable time. The focus on entry- and exit-transitions – to be discussed in more detail in the following section – seems to offer an excellent opportunity to engage in such a process of inquiry.

3 Research Program



Modern risk management is relying as far as possible on quantitative methods. These come in two major kinds, one close to the world of engineers, the other to the world of economists. Both rely on mathematical concepts and methods, and both are embedded in discourses of a less formalized kind, drawing on notions form the world of the humanities. One of the most important notions of this kind when dealing with risk and uncertainty is the idea of individual rationality.

According to this idea, an individual can be rational all by itself. She may or may not be faced with other individuals, and if so these other individuals may or may not be rational – it is always possible for the single individual to be rational in her decisions and actions. And being rational here means being consistent. In this view, it is irrational for somebody to smoke if she cares about her health and knows that smoking causes cancer. But it is not irrational for somebody to risk her life by climbing in the mountains if she enjoys the adrenaline flow triggered by that risk.

The basic unit of analysis then is an individual agent with given preferences and a given situation she finds herself in. That agent may be a physical person, a household, a business, a political institution, etc. If the agent is faced with some risk, one can always ask what is a rational choice in the face of that risk. And in fact risk management over the past centuries has evolved mainly as an effort to find and implement choices that are rational in this sense.

Markets, institutions, societies are then looked at as aggregates of rational agents. And in this tradition of inquiry one has tried time and again to identify situations where aggregates of rational agents behave as rational agents, too. Such situations are then said to lead to congruence between individual and collective rationality. This turns out to be possible when the differences between the agents to be aggregated can be neglected – leading to the device of a representative agent – and when moreover there are no external effects.

Clearly, the former condition rules out differences in values, tastes, etc., while the second condition rules out free, but scarce public goods like education, clean water, etc.

Global environmental risks are then analysed as "tragedies of the commons" (Hardin 1968), i.e. as situations where the second condition is not met. Various devices can be introduced to achieve the desired congruence between individual and collective rationality. In one way or another the relevant devices establish exclusive property rights for resources that without these rights could not be allocated unambiguously to single agents.

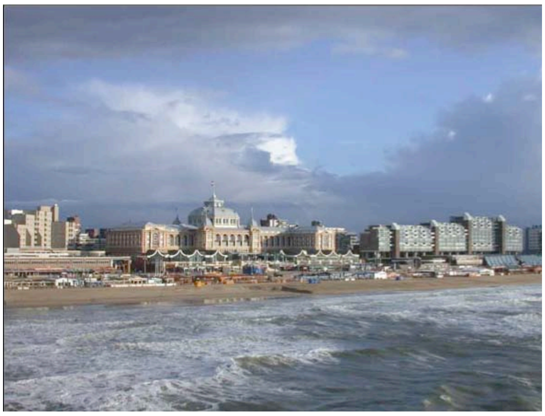
Establishing and maintaining the property rights that lead to congruence between individual and collective rationality is the focus of the economic approach to risk. A new kind of insurance contract, say for flood damages, then introduces a new property right, and at least in theory this might suffice to achieve an optimal compromise between avoiding such floods by suitable measures and accepting them to a certain degree, compensating the resulting damages with the payments following from the insurance contract. Under suitable assumptions, the cost of purchasing such insurance does indeed provide the incentive for actions that are both individually and collectively rational.

The engineering view of risks enters the picture by assessing the probabilities of various possible consequences and the measures available to reduce the probability of adverse consequences. The dramatic differences in the death toll of earthquakes in developing countries and earthquakes of similar strength in highly industrialised countries are testimony to the paramount importance of engineering in dealing with risk. While the economic view of risk sets the stage for individual and collective rationality to coincide, the engineering view enables agents – individual and collective – to act on that stage.

In recent years, a broader view of human action has emerged out of studies of coupled man-environment systems. In the management literature, since several decades the study of socio-technical systems has produced important insights on organizations engaged in activities as diverse as mining, manufacturing, computing, communicating, etc. (Emery and Trist 1965, Zha et al. 2006). More recently, the study of environmental problems has led to a view of human action as embedded in socio-ecological systems. These are systems of human beings operating in a shared environment and drawing on the resources of a shared language (Crawford and Ostrom 1995).

Young et al. (2006) explicitly frame an agenda of scientific research in terms of socio-ecological systems (SES). They do so by stressing the profound changes that SES at all scales – from mountain villages to multi-national companies – are experiencing because of the increasing global connectedness that is affecting them. The research program of IRG-project is designed as an integral component of this agenda.

3.1 Socio-Ecological Systems



Humans are not alone; they are part of complex socio-ecological systems (SES) (Gallopín 1991), also labelled as social-ecological systems (Berkes and Folke 1998), as coupled human-environment systems (Turner et al. 2003), human ecological systems (Jaeger 1994) and in similar ways.

SESs can be found at all scales, from the local household with its surroundings to the society of nations inhabiting planet Earth. In any SES, human and ecological (or environmental, or natural, or bio-physical) subsystems interact. This is important for IRG-project, because risk, and particularly the impact of an event or perturbation when it materializes, often affects not only humans but also the environmental subsystems with which they are connected, thereby impinging on human coping capacity (e.g. when a flood erodes the soil, it affects the productivity of the land and the economic condition of the farmers, leading to a reduced capacity to cope with further floods).

For the purposes of this discussion, the SES can be conceptualized as composed by the following subsystems in interaction: social, economic, ecological, and institutional (Figure 1). The coping capacity of the SES as a whole is linked to the four subsystems, but human coping capacity obviously resides in the institutional, social and economic subsystems.

A key aspect of the current wave of globalization is the fast increasing connectedness (Young et al 2006) of the global socio-ecological system (SES), both within the human sphere (e.g., economic interdependency, flows of trade, information, and people; networks of telecommunications, etc.) and the natural sphere (where there is an augmentation and intensification of the global linkages among the biotic and abiotic processes in land, oceans, and atmosphere). Furthermore, as human activities intensify, interconnect and extend to the global scale – in such polymorphic ways as international trade, communication networks, cultural convergence, global crime (Held et al. 1999) – they also start to link with ecological processes operating at the same (or smaller) scales.

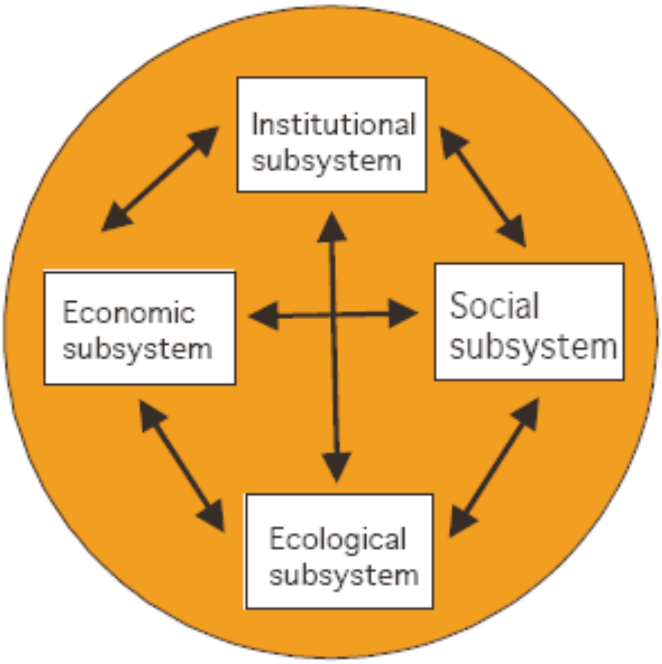
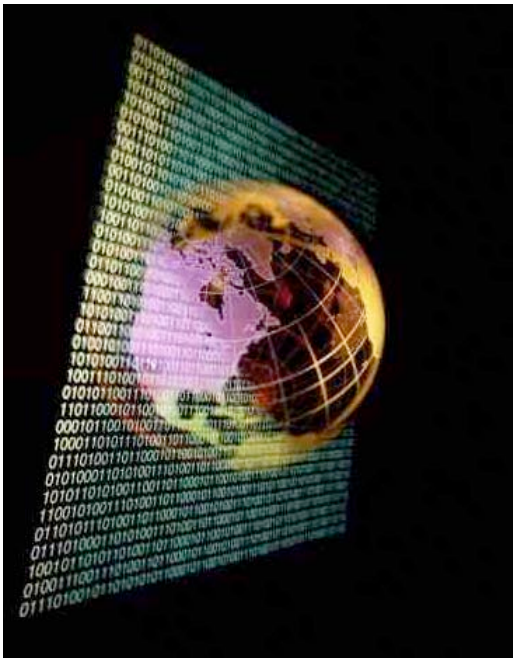


Figure 1: Socio-Ecological System

Changing connectedness has many different implications for the resilience of a system. Increasing connectedness leads to faster spread of information, populations, and decisions, but also of viruses, and diseases. While in some senses an increased global connectedness is essential for improving the governance of global, systemic risks, high connectedness also has other consequences for governance. In a "wired world" disturbances rapidly transfer across markets and societies, ramifying the effects of change. In such a situation, the sources of change in the global SES may arise far away from the impacts. Accordingly, the costs and benefits of policies become fuzzier, and the world more uncertain. From the institutional side, important adjustments and even the creation of new kinds of institutions may be needed to deal with this situation of 'distributed causality'.

But there is a more worrisome side to increasing connectedness. It has long been established (Gardner and Ashby 1970, May 1973) that in networks whose components are connected at random, an increase in complexity leads almost inevitably to the destabilization of the system. This means that increasing (at random) the number of connected elements, increasing the density of links or connectedness, and/or the strength of the interactions between linked elements, increases the probability of the system becoming instable. These studies suggest that the increase in complexity and connectedness (especially non-evolved and non-planned connectedness) may lead to decreased stability and increased vulnerability, and to a sharp increase in the costs or error. Globalization is increasing the connectedness of the global SES, and also the strength of many of the linkages and, while the newly evolving global SES is certainly not a random network, the new linkages are certainly not the last ones added.

3.2 Entry- and Exit-Transitions



Risk is a concept that denotes a potential negative impact that may arise from a future event, and is different from the actual occurrence of the event. Perturbation, stress, hazard, or shock are terms denoting threats to a system, either sudden or gradual. The relation between risk, occurrence of the hazard, and entry and exit transitions can be illustrated in a very simplified way as in Figure 2.

Risk is caricaturized here by increasingly threatening signals: cloudiness and heavy rain. There is no transformation of the considered SES until the perturbation materializes (i.e. the full manifestation of the thunderstorm). In this illustration, the impact of the perturbation upon the system leads to a transformation of the SES, including the human coping capacity (because, by definition, in the cases considered in IRG-project the risk exceeds this capacity).

The transitions "in" (entry) and "out" (exit) are processes that occur before and after the hazard materializes, although in some cases they may extend in time absorbing the interval in which the perturbation manifest itself (e.g., in the cases of continuous or for cumulative perturbations).

Our focus on entry- and exit- transitions builds on previous work on the social amplification of risk (Kasperson et al. 1988, Kasperson and

Kasperson 1996, Lofstedt and Renn 1997, Pidgeon 2003). Risk experiences are rarely intelligible without considering the communication processes that shape not only the salience, but even the very definition of what is happening. In the risk community, an awareness of this situation has led to far-reaching reflections on the relations between science and society (Stilgoe et al. 2005).

In this perspective, the concept of transition will be explored in detail as part of the research activities of IRG-project. This includes its relation to concepts of phase transition and related concepts in other fields of inquiry. We expect that this will also contribute to further clarify the broad and important notion of a sustainability transition (NRC 1999, Raskin et al 2002, Elzen et al. 2004, Adams and Jeanrenaud 2008).

For the time being, an entry transition will be defined as the sequence of changes in the decision-making processes, including the deployment and re-organization of actions, actors and resources, that is associated to the preparedness of the human components of the SES to cope with the risk.

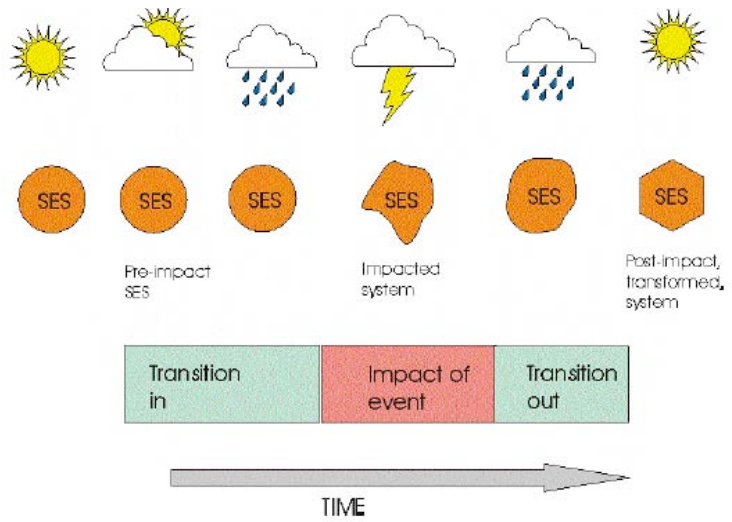


Figure 2: Entry and Exit Transitions

An exit transition is the sequence of changes in the decision-making processes that takes place after the event has materialized, indicating the return of the coping mechanisms and actors and the underlying structures and processes back to the "normal" situation (if the disturbance did not overwhelm human coping capacity) or to a new condition or transformed system (indicating that human coping capacity has been exceeded by the perturbation).

It should be noted that the transformations of the coping capacity may be different from the transformations suffered by the SES as a whole (losses of lives, economic losses, etc) as a consequence of the impacts of the events. They may be:

Positive: when the new system or condition has incorporated learning, showing increased robustness, improved effectiveness, etc. leading to an improved human coping capacity in comparison with the pre-perturbation situation.

Negative: when the net result of the occurrence of the hazard leads to a weakened human coping capacity, forgetting of the lessons learned, etc. making the system more vulnerable to future risks.

A number of questions need to be answered in the course of IRG-project in order to develop practical criteria that could be used to improve governance in concrete risk situations. For instance, when does the entry transition begin? With the initial perception of the risk, with the first operational changes in the decision-making mechanisms, or when a full alert system is in place? When does it end? When the hazard materializes, when the exit transition begins? Similar questions need to be answered for the exit transitions.

3.3 Illustration: Early Warning Systems

In the particular case of entry strategies, early warning is playing a great role in minimizing both loss of live or injuries, as well as material and economic losses (BMBF 2004, Bussiere and Fratzscher 2006, Herman et al. 1997, Scheffer et al. 2008, Wagner and Tsui 2001). For example, the 26 December, 2004 tsunami provoked over 250,000 fatalities.

As stated by the International Strategy for Disaster Reduction of the United Nations, UN-ISDR, and by the Director General of the Office for the Coordination of Humanitarian Assistance, UN-OCHA, should there have been a tsunami early warning system in place in the Indian Ocean, the number of people killed and injured would have been reduced dramatically. But it is not enough to have some early warning system in place, it is also essential to design it so as to facilitate the learning processes required to deal with the relevant phenomena (Chabay 2004).

In a similar case, the European heat wave in the summer of 2003 provoked at least 70'000 fatalities (Jaeger et al. 2008). Should there have been an efficient early warning system in place, nearly all of these fatalities could have been avoided.

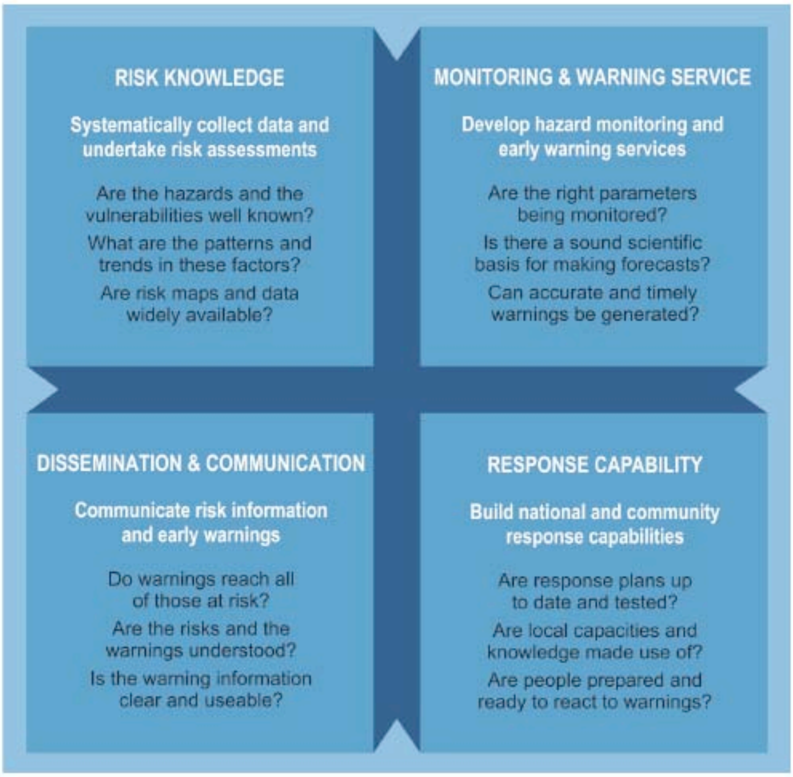


Figure 3: Critical Aspects of Early Warning Systems

These two examples point to the effectiveness of early warning systems in reducing the impact of natural events. Early warning systems are one of several examples of "entry" type transitions which allow institutions to cope with disasters in a more efficient way. It is important to recognize the need to promote "people-centred" or "end-to-end" early warning efforts, which ensure that the population at risk is targeted with such warnings, and that such people understand the warnings and know how to react to them. On the occasion of the Third International Early Warning Conference in March 2006, the Platform for the Promotion of Early Warning introduced four elements that are vital for efficient early warning (figure 3).

As can be seen, in addition to the typical elements related to monitoring hazards and disseminating the warnings, critical elements to consider in the context of efficient early warning are:

- The identification of vulnerable groups of the population, and in particular their location, so that warnings can reach such groups as quickly as possible.

- Ensuring that warnings are understood and reacted upon by vulnerable groups, and that such groups are aware of how to react if such warnings are issued.

3.4 Models and Modeling

Broadly speaking, the community of risk analysts consists of three quite separate groups. First, there are the people trained in economics who take it for granted that some version of expected utility is the ultimate yardstick in risk management. Second, there are the engineers and natural scientists who feel comfortable with quantitative assessments as long as they relate to physical quantities and standard statistical techniques. And third, there are social scientists who emphasize issues of meaning and interpretation.

In general, there is little dialogue and even less cooperation between representatives of the three groups. IRG-project will consciously bring together researchers with these different kinds of background, and it will combine concepts and methods of a more qualitative character – in particular comparative case studies in the style of grounded theory – with quantitative approaches – in particular simulation models based on quantitative data (Shi et al., 2000).

Figure 4 offers a first sketch of what it can mean to model entry- and exit-transitions of risk occurrence.

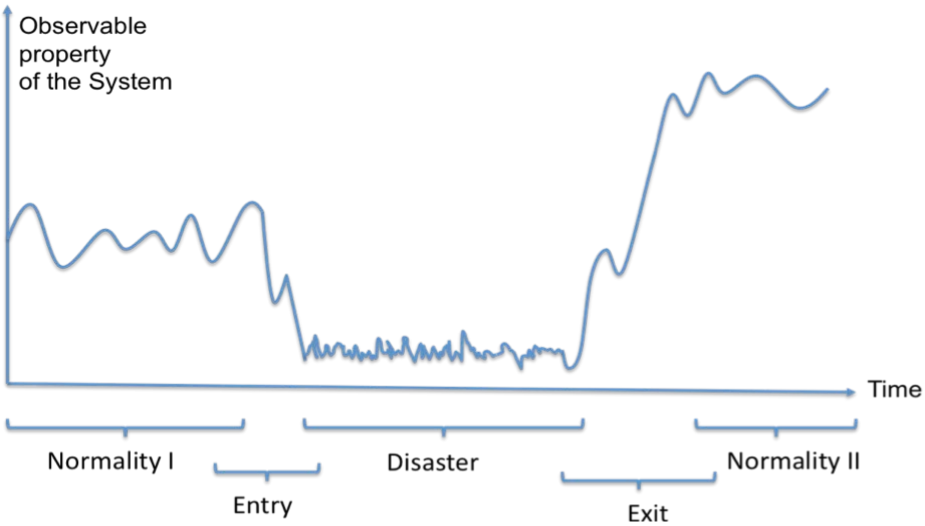


Figure 4: A Minimal Model of Entry- and Exit-Transitions

The relevance of this kind of dynamic modeling is perhaps best explained in relation to the view of economic systems as governed by an equilibrium of supply and demand (figure 5). In this view, there is a single equilibrium from which the economy may be nudged away by exogeneous shocks, but to which it will return sooner or later.

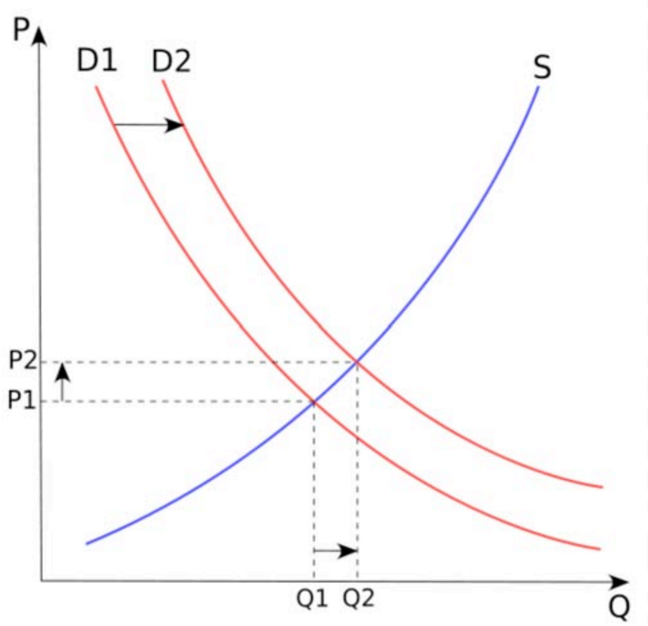


Figure 5: The metaphor of supply and demand

The position of the equilibrium may shift due to external circumstances – e.g. discoveries of new technologies or shifts in tastes – but this does not change the fundamental process. Policy-makers may wish to induce such a shift of the economic equilibrium in order to internalize some external effect. An example is the wish to reduce the risks of climate change resulting from the fact that todays agents can burn fossil fuels without having to pay for the damages this may cause later on. In this case, policy will have to shift the demand schedule (e.g. by increasing demand for renewable energy) or the supply schedule or both. This can be done by modifying prices through taxes, subsidies, tradeable permits, and similar instruments.

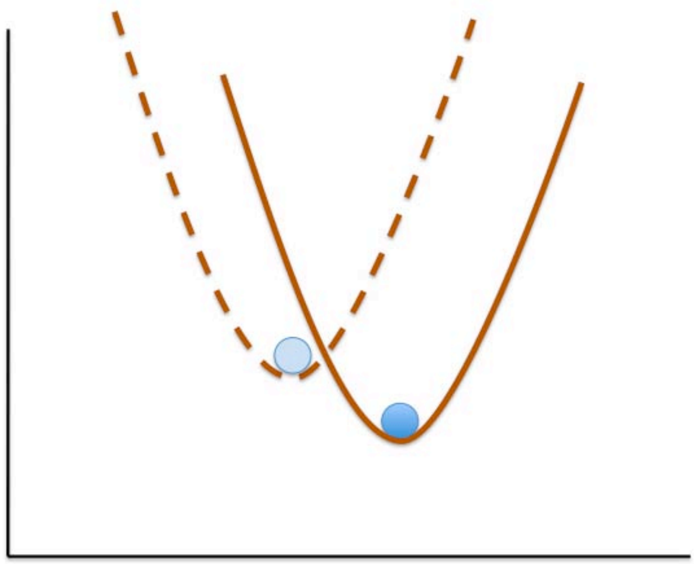


Figure 6: A one-equilibrium system

The metaphor of the invisible hand, as framed by the standard idea of an equilibrium of supply and demand, then leads to a view of the economy as one-equilibrium system (figure 6). A suitable measure related to the difference between supply and demand defines a trough in which the system moves around as if it was subject to a force of gravity combined with friction: exogenous shocks lead to random oscillations that are damped in the course of time. This is the basic structure of the so-called DSGE (dynamic stochastic general equilibrium) models used by central banks and many research institutions. None of these models, however, was able to foresee even the possibility, let alone the timing, of the financial crisis that set in in 2008.

In the one-equilibrium picture, a transition to sustainability requires changing some parameters of the system as a whole so as to move its equilibrium around while maintaining the dynamics that let the system converge to its unique equilibrium.

However, it is well-known in the theoretical literature – although unfortunately ignored in most practical policy measures – that in a system of inter dependent markets more than one equlibrium results. This is the content of one of the most important findings of mathematical economists in the last decades, the so-called Sonnenschein-Mantel-Debreu theorem (Kirman 1992). This result would hold even in a world where the future prices of all goods and services could be known in advance. It is even more relevant in a reality where the future is largely a matter of guesswork, so that different guesses lead to different equilibria.

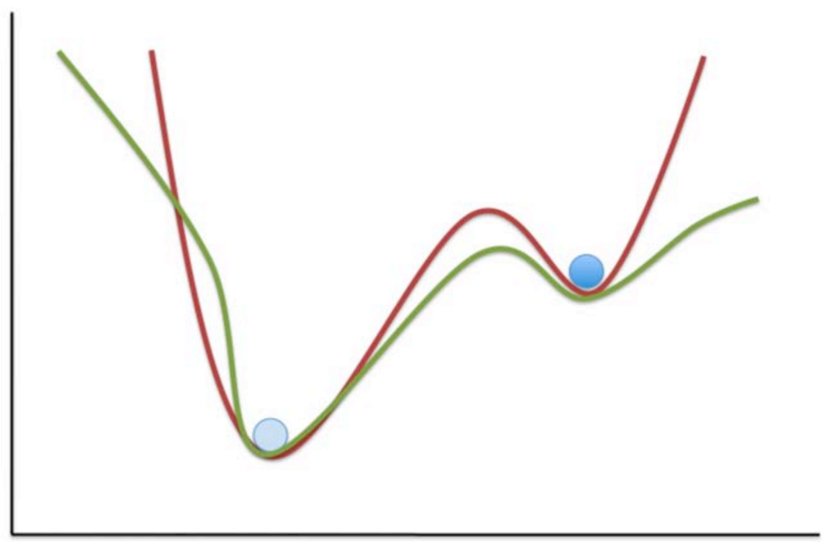


Figure 7: A multi-equilibrium system

As a result, the economy we live in behaves like a multi-equilibrium system (figure 7), where random shocks can lead to a shift from one equilibrium to another one. And it is this shift, with its entry- and exit transitions, that is represented by models like the one sketched in figure 4. In the case of risk occurrences, the absence of learning may lead to a return to the previous equilibrium, while processes of social learning may enable it to achieve an equilibrium better suited to deal with similar risks in the future. But of course a risk occurrence may also disrupt a system in such a way that it will actually move into a state of greatly increased vulnerability.

Models of entry- and exit-transitions need to distinguish between these possibilities, and that would be impossible with single-equilibrium models. Moreover, usually non-monetary factors like institutional arrangements need to be considered together with monetary processes. In particular, the interaction between various risks in a socio-ecological system is structured by a variety of conventions that evolve in the course of time (Young 1993, Yoon 2006). This process is particularly important in view of market dynamics (Gintis 2007) and should lead to a new generation of models of socio-ecological systems, models that involve heterogeneous agents, combine monetary and non-monetary processes, and display multiple equilibria as well as shifts between them with their entry- and exit-transitions.

To develop this kind of models, databases about risk occurrences are essential (Shi et al. 2000). However, for many important aspects of such models quantitative data are hard to find. E.g., it is quite difficult to produce reliable estimates of damages from large environmental disasters. IRG-project will use advanced methodologies suited for this purpose and develop them further. An interesting example is given by disaster chains. They structure disasters into a hierarchic causality graph. For assessing the risks imposed by specific disasters, one decomposes the risks of each node of a disaster chain into probabilities and losses and applies specific modeling approaches to estimate them.

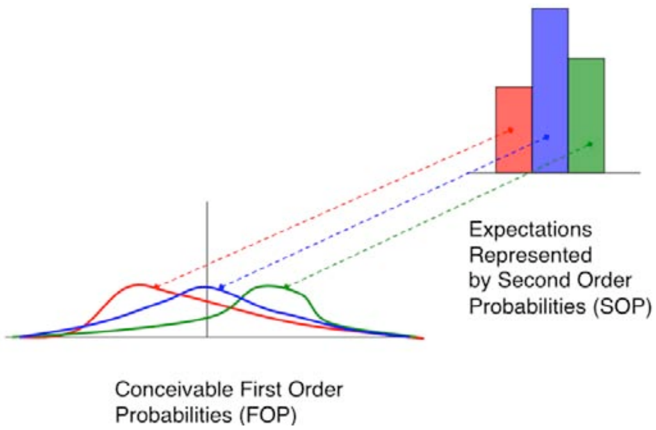


Figure 8: Bayesian risk assessment I

We will use this technique in the perspective of Bayesian Risk Management:

i) *Probabilities* A disaster chain can be modeled as a Bayesian Belief Network (BBN). In such a network, the probabilities and conditional probabilities of specific nodes may first be derived by applying methods of "hardcore" or "softcore" Bayesianism. When time series are available, hardcore Bayesianism uses mathematical algorithms for statistical inference. When they are not, softcore Bayesianism uses expert elicitation for identifying the probabilities.

Sometimes, it will be useful to represent beliefs about possible futures by using second order probabilities (Jaeger et al. 2008, see figure 8 below). A range of possible futures is then represented as a set of stochastic scenarios, and the relevant beliefs are represented as weights attached to those scenarios.

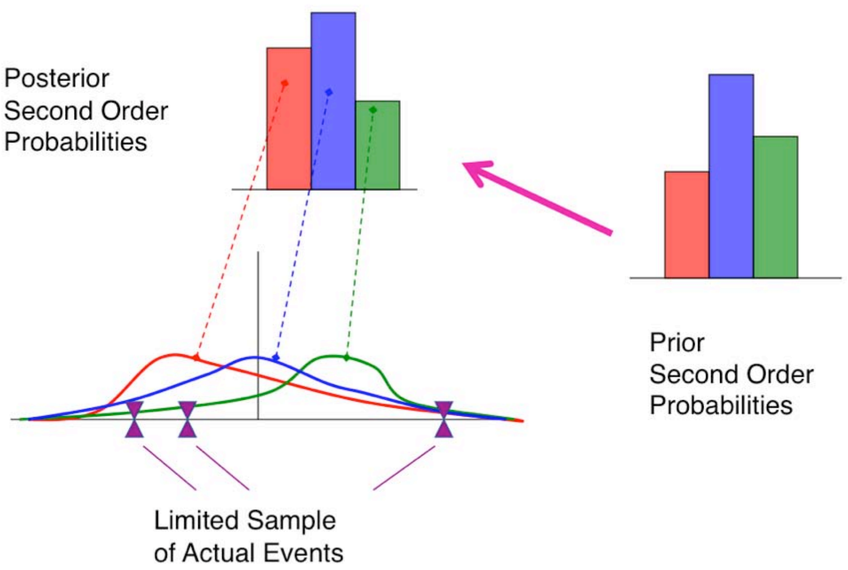


Figure 9: Bayesian risk assessment II

Once the BBN is set up, it can use any incoming information for updating its probabilities (figure 9). Again, these could be done using measurement and data that add to existing time series, or new rounds of expert elicitation.

ii) *Losses.* Regarding losses of specific disaster nodes, we will distinguish between direct and indirect losses. For disaster nodes where historic experience is available, we can base our analysis on historic figures. An important distinction must be made between direct and indirect losses. Accounting for direct losses is a cumbersome but well-established procedure. The complication here is to judge whether historic figures can easily be extrapolated. For assessing this, we will apply methods of hardcore Bayesianism. The same methods may also help us identify structural breaks in historic figures that we must account for. Assessing indirect losses of a disaster event, however, poses a challenge. Here, we want to apply innovative methods like the one pioneered by Hallegatte (2008). He used an adaptive regional input-output model for assessing the economic losses of hurricane Katrina in the Louisiana region.

These techniques are essential for assessing the future growth of damages from various kinds of disaster (figure 10). Since several decades, e.g., the growth rates of – insured and uninsured – losses from weather related disasters exceed those of GDP by several percentage points. As a result, in a few more decades all of GDP would go into compensation for such disasters. Clearly, this will not happen; but how will the present trend come to an end? Most likely by processes of social learning that enable people all around the world to better cope with weather extremes. These processes will probably be triggered by entry-transitions of extreme events, and they will need to consolidate in the exit-transitions.

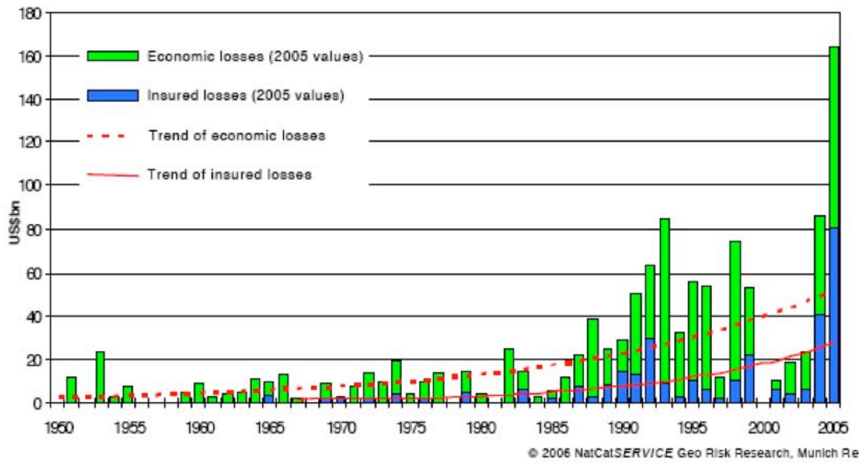


Figure 10: Growth of damages from weather related disasters

Both when dealing with direct and indirect losses, we may encounter situations where social and climate change invalidate past data. In such cases we will apply tools from softcore Bayesianism for eliciting loss distributions to expect from experts. Once we will have identified both probabilities and losses to be expected, we will recombine them in order to come up with quantified risks. For studying management dynamics of large-scale risks, we will model the social interaction of societal actors. The actors themselves we will model as Bayesian belief agents. A Bayesian belief agent has expectations in the form of knowledge-based probabilities for events or processes that are relevant for him. He updates these knowledge-based probabilities when new information becomes available for him. New information may be generated by natural dynamics, or by the dynamics of the social system.

With this background, we will model basic patterns of endogenously generated mutually induced updating processes of personal beliefs. In our opinion, a basic understanding of such endogenously driven updating processes is indispensable for comprehending the social dimension of managing large scale risks. Remarkably, this applies to managing large scale natural risks like earthquakes or extreme whether events (both sudden or slow onset) as well as to managing socially generated risks like financial or political crises.

Rapid loss estimation (RLE) is the near real time estimation of casualties, injuries and economic damage based on loss modeling, pre-event databases and other information, and near real time estimation of the hazard parameters. RLE is critical to understand how far a social system is from its ordinary state and to what extent extrinsic intervention is needed to return to its original state or transform to a new equilibrium state.

Giving that the occurrence probability of large-scale disasters is relatively small, models of loss assessment and risk quantification based on historical events may be misleading for the purpose of rapid disaster evaluation and emergency management. Models of rapid disaster evaluation based on the real-time disaster information and data obtained from various means such as remote sensing images, local media, verbal information and messages from impacted regions etc. become effective and efficient tools that can be easily adopted and implemented by government and emergency agencies. These models can also be used to estimate the impacted areas and populations of present and the near future.

Before this background, a conceptual model for early warning (entry), risk assessment and loss estimation, emergency response, recovery, reconstruction, risk transfer and integrated risk governance of multi-hazard disasters will be developed.

Natural catastrophe models are now widely used in insurance industries for "Nat CAT" risk pricing and portfolio management. These models focus on the quantification of probable maximum loss (PML) and excedence probability (EP) of individual peril, and the direct losses of buildings, contents, business interruption etc. are estimated. However, the indirect losses and losses due to secondary disasters such as mountain flood followed by large earthquake are usually not estimated. In this science plan, we propose to shift the focus of development of individual peril models to multi-peril platforms in which the risk of multiple hazards generated from a large-scale disaster can be quantified systematically and the risk at different stages of disaster relief, emergency response and recovery can be monitored.

Very large scale disasters (VLSD) usually develop as disaster chains – rather than as individual disasters – as a result of interaction of geosphere, biosphere, hydrosphere, atmosphere and the social system. Therefore, individual hazard or multi-hazard methods may underestimate the intensity or complexity of VLSD.

The disaster chain methods for assessing VLSD have been developed to provide a comprehensive understanding of logic relationships and correlations between various hazards driven by a single large-scale disaster. The development of models of disaster chains aims to quantify both individual and integrated losses and risks so as to first identify and then manage unexpected circumstance that might otherwise be unduly neglected.

3.5 Comparative Case Studies

Methodologically, IRG-project will follow a grounded theory approach (Glaser and Strauss 1967). We follow this route in a pragmatic mode, in order to create the intellectual space for discoveries about what it means to "manage the unexpected" (Weick and Sutcliffe 2001). In this perspective, the key point about grounded theory is the willingness to expose ourselves, the researchers, to the unexpected as well, but to do so in a methodologically controlled way.

We start with the concepts of socio-ecological systems and of entry and exit transitions introduced in the previous sections, and with the broad conjecture that:

- entry transitions determine to a considerable extent how well the socio-ecological system in question will be able to deal with a risk that exceeds its current coping capacity;
- exit transitions determine to a considerable extent how well the system in question will be able to learn from past risk occurrences in view of future risks;
- resilience and vulnerability of socio-ecological systems are particularly visible during entry and exit transitions.

This threefold conjecture will then be stepwise refined and modified on the basis of data and theoretical reasoning. The notion of "theoretical sampling" plays a central role in grounded theory (and has interesting similarities with sequential experiment design in laboratory experiments with physical systems characterized by large numbers of degrees of freedom).

We will use this idea by first defining two case studies that *prima facie* offer major contrasts in view of our initial conjecture – interesting candidates are the Chinese winter storms of 2008 and the European heatwave of 2003, but also the floods of 2008 in Iowa, U.S., and in Southern China. These cases will then be carefully investigated, and on the basis of this investigation a next group of cases will be selected in such a way as to introduce additional contrasts to the ones found in the first round.

In this spirit, a suite of case studies will be used to develop a conceptually dense theory on the basis of new observations, combined with the use of modelling and other tools. This process holds promise for innovative descriptions and explanations of key features and mechanisms – and for formulating concrete applied improvements of existing risk governance settings. Therefore, a set of carefully selected case studies will provide a central source of information and analysis for IRG-project. It is appreciated, however, that to be effective such case studies must be tightly grouped to reflect research questions and objectives (Amendola et al. 2008). Each one should be designed to be a case study of some central issue or hypothesis tightly linked to conceptual or methodological issues whose analysis will further the understanding of entry and exit transitions and how they may be improved.

Designing an effective set of case studies involves a series of methodological issues (Yin 1984). To ensure that each case is soundly designed and structured, the project will identify a limited set of conceptual issues that each case will be expected to answer. Each case is envisioned to require three years of research and preparation and will be reviewed by the project steering committee and other case study authors annually. These reviews will not only provide continuing peer review but will also serve to draw the studies together into a common format and approach.

To date, a number of potential cases have been identified and are being explored.

Besides the floods mentioned above, they include

- the 2008 ice storm in China
- the 2003 European heat wave
- the Katrina hurricane in the U.S.
- the 1995 Kobe earthquake in Japan
- the 2004 Indian Ocean tsunami

- the 2008 Wenchaun earthquake in China
- the African droughts and food crises
- the 2008 financial crisis
- the pressure on food prices from biofuels
- the avian-flu epidemic

Attention will also be given to the complex array of risks associated with rapid urbanization in China and other parts of the world. In addition, consideration will be given to novel or new risks, such as cybernetic failures or terrorism, or the potential for future disease epidemics. To ensure comparability between case studies – a major need – a common case format and protocol will be formulated.

Case studies tend to be complex because they involve multiple data sources and produce large amounts of data for analysis. Also, not all independent parameters can be expected to be identical between case studies – in contrast to laboratory experiments. Yet, this aspect provides the case study approach with the advantage of applicability to real-life, contemporary human situations, such as entry and exit strategies in future risk management situations which reflect positive elements of past cases. The case study comparisons contribute to developing a robust platform upon which to develop a typology of risks and of possible strategies to deal with them.

The case studies are focused on four forms of risk:

- environmental risks
- health-related risks
- socio-economic (e.g. sub-prime)
- technology related risks

The focus will be on the first category, but never in isolation. Each case study will be oriented towards possible insights and lessons that are useful in view of global risks. A clear case study comparison analysis provides the scope to disentangle cultural differences and state-type differences (developing, emerging, or developed; strong and weak) from other elements contributing to the entry and exit transitions adopted by various actor-types in each integrated risk case study. Namely, such comparison begins to address the IRG-project research question of: "Who (or which regions) can do what in order to improve entry and exit switches and thus risk management?" Thus, through case study comparison IRG-project highlights approaches to dealing with risk that can be appropriately expanded and implemented in a realistic world system.

Two case study comparison types are of great interest as learning tools:

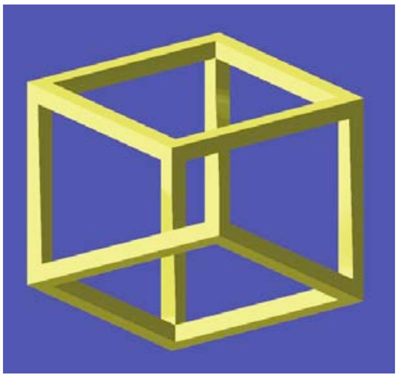
- studies comparing similar risk outcome types in different countries (i.e. China's Wenchuan Earthquake vs. Japan's Kobe Earthquake) and

- studies which compare responses by different nations in the global context when the same risk outcome effects multiple nationstates (the 2003 European heat wave in various European nations).

Both types of comparisons will be systematically pursued in the course of IRG-project. Still, it is important to emphasise the following points from the outset:

- case studies will be selected and performed sequentially, gradually increasing the number of studies to be performed in parallel;
- the research will proceed through an interplay of empirical and theoretical reasoning that will yield useful output already in the first years of research;
- major insights to be gained are likely to crystallize around specific discoveries that may emerge after several years of careful research;
- starting from single discoveries, systematic understanding will be sought, until a more fundamental logic of the relevant processes can be made explicit.

3.6 Governance and Paradigms



Generally, a disaster event consists of hazard, hazard-affected bodies and hazard-formative environment. As a complex system, a disaster system has the common characteristics of such systems, namely multilayer system architecture, intertwined system functioning and nonlinear system process (Shi 1991). In particular, one may distinguish between mechanical and emergent processes – the former obeying some well-defined law without much novelty arising in the course of time, and the latter unfolding in highly surprising ways time and again.

The integrated disaster process is an integrated system of mechanical and emergent disaster dynamics, where the two are linked by mutual feedbacks and interactions. A general action mode of the process is discussed by Shi et al (2005), namely "disaster area / disaster victim / disaster effect" amplifying and reducing both the mechanical and the emergent processes.

Due to the complexity of the integrated disaster process, it is necessary to adopt an integrated mode when implementing risk management measures (figure 11).

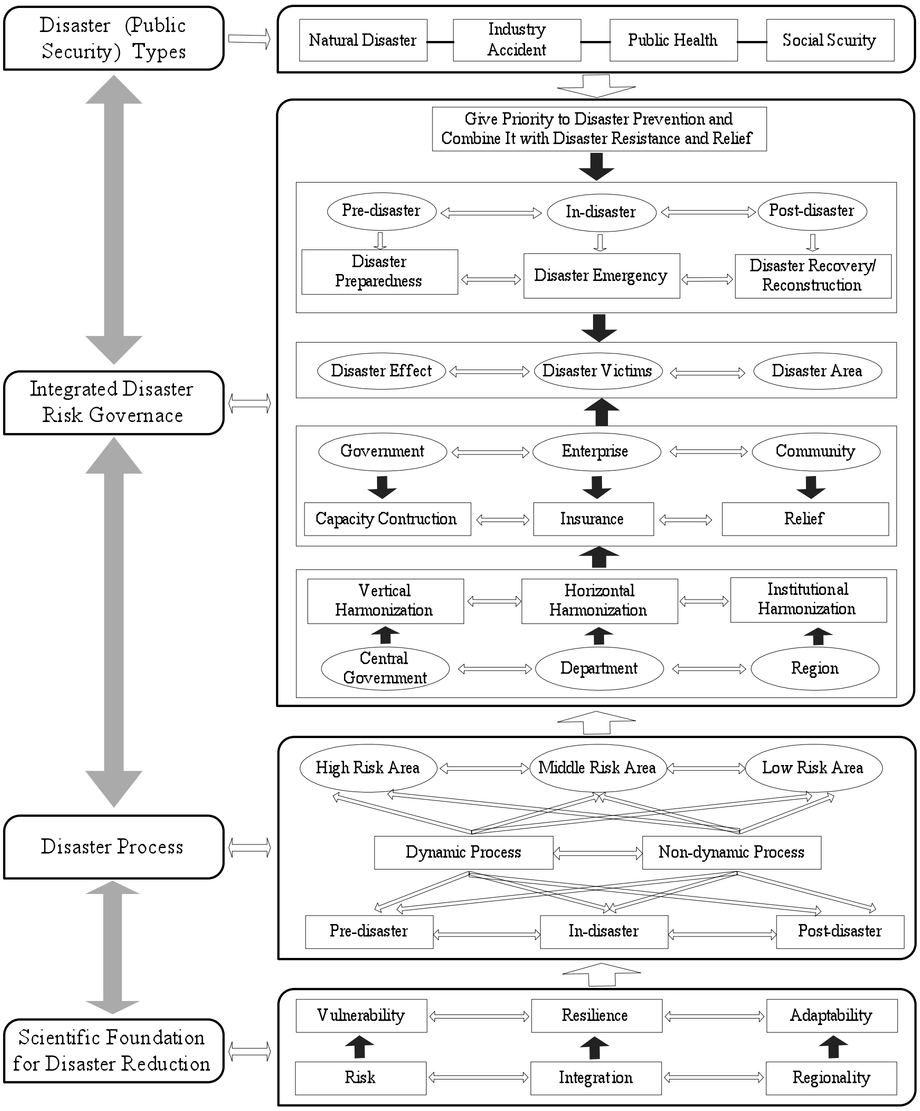


Figure 11: Integrated Risk Governance Mode

In fact, the cognition of integrated disaster processes in the academe is of core status in the disaster research all the while, and becomes an essential theoretical problem of disaster science research. Wisner et al. (2003) put forward the "pressure-release" model (PAR) of the disaster forming process, which is used to explain the evolution of vulnerability (Villagrán de León 2006); Burton et al. (1995) initiated the "adaptation and adjustment" model (DAA) of the disaster forming process, in order to explain the evolution of adaptability; Mileti et al. (1999) defined the "integrated effect model among geophysical system, human system and frame system" (ESC), aiming at introducing the evolution of resilience; by recognizing the structure and functioning of urban nutrition system at five different levels, Okada (2004) established the "pagoda model" (PM) to describe the disaster forming process.

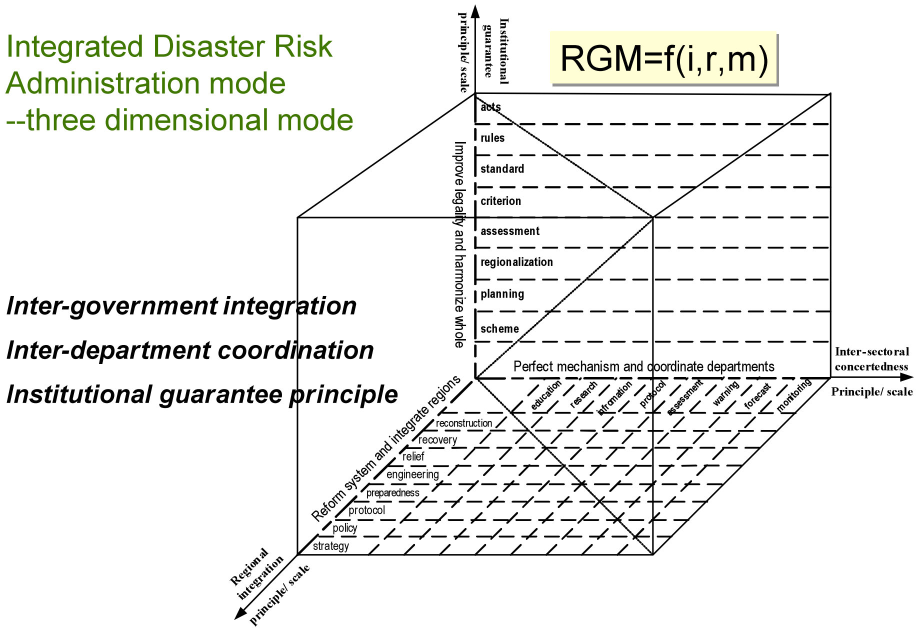


Figure 12: Integrated Risk Governance Mode II

Based on the characteristics of the integrated disaster process and the aforementioned models, Shi et al. have proposed an integrated risk governance mode (figure 11 and 12; Shi 2005, 2003, 1991; Shi et al. 2006a, 2006b, 2005a, 2005b). From the perspective of disaster management, this mode clarifies the responsibility among the central, departmental and local governments and promotes an integrated disaster administration management system. In this system, governments of all levels cooperate to realize the "vertical to the end and horizontal to the margin" integration.

From the perspective of the disaster process, the integrated mode elaborates the overall planning before, during and after a disaster to realize the integration of disaster preparedness, emergency, recovery and reconstruction. From the perspective of the relevant disaster departments, it emphasizes the harmonization of governments, enterprises and communities to realize the integration of disaster capacity construction, insurance and relief. The three types of integration mentioned above are the core content of the integrated disaster risk governance mode.

Although the general properties of the integrated risk governance models were well demonstrated, or at least to some extent, in the community of risk research, there remains a huge gap between the common theory and methodology of integrated risk governance and their application for an individual large scale disaster occurring in a given region.

There are two principal elements contributing to this gap. One is the fact that a large scale disaster for a certain region usually is an event of very low possibility of appearance at a larger scale. It is very hard to make a useful prediction and to take tailor-made governance all the way to a specific large scale disaster in a given region, or even to investigate its probability and to roughly project its damages. So far, most of the large scale disasters have been recognized as unpredictable random events.

Another reason is that even if one knows a similar disaster will happen, it is still difficult to make an appropriate response or action plan since no perfectly proper example can be found. There always are important differences between socio-ecological systems – differences of the social administrative system, the stage of development, capacity building, levels of science and education, culture, etc.

Therefore, it is very urgent to develop some quasi-operational paradigms to follow for regions of some similarity in at least some of the above mentioned features. With the help of such paradigms, once a large scale disaster appears, society can take suitable measures based on previous experience. And these paradigms can only emerge through studies of socio-ecological systems with their entry- and exit-transitions.

For example, some developing countries faced by an earthquake may take advantage from the paradigm used in the Chinese government's response to the Wenchuan Earthquake in Sichuan on May 12, 2008. This paradigm in turn was informed by the Chinese winter storm at the beginning of 2008 and by many other cases. Or some developed countries faced with hurricanes and storm surges may learn from the paradigm the US government enacted after hurricane Katrina in 2005. And of course learning at the level of such paradigms is not a matter of simple imitation, but of analysing previous cases in view of the interplay between disasters, institutions, physical processes, and human actions.

The more paradigms can be investigated and summarized for different large scale disasters related to socio-ecological systems in different regions, the better. There is no panacea for dealing with disasters, but there is an opportunity to learn to improve current practices at all scales, from the local community to the whole globe.

4 Outcomes

Complexity is a key feature of socio-ecological systems, and surprises lie at the heart of risk management. Integrated risk governance cannot evolve as the mechanical application of a few general principles. It requires familiarity with a wide variety of specific situations along with the ability to creatively use rich concepts – like the ones of entry- and exit-transitions – in order to see analogies and differences between those situations when addressing a newly arising problem. IRG-project will produce this kind of insights. It will do so with a focus on the entry and exit transitions of risk occurrences that exceed current coping capacities.

In particular, IRG-project will produce insights on what kinds of transitions can be expected to be helpful, and which ones should rather be avoided when facing specific risk challenges. We will embed these insights in the broader knowledge basis currently available in risk studies and convey them to different groups of practitioners.

Of course the primary way to communicate scientific findings is via papers presented at scientific conferences and texts published in journal articles and scholarly books. Such will be the routine of IRG-project, too. We will pay special attention on joint papers produced by researchers from very different background – in terms of scholarly specialization, geographical origin, gender and age. And we will foster a culture where each researcher involved in IRG-project produces a continuous stream of publications, rather than operating in the too frequent mode of publications arising only in selected periods of time by selected individuals.

Finally, we will pay attention to the balance between insights focussing on understanding the dynamics of various risks and insights focussing on improving the practical efforts at dealing with those risks. We see the relation of understanding and action not as an asymetric hierarchy in either way, but as one of mutual support between two basic modes of the human condition.

Besides scholarly publications, there will be an on-going interaction with mass media, including recent media like the internet. We see this as a natural process that will become part of the routine of IRG-project, but we do not see the media as a primary focus of our outreach effort. The reason for this is that IRG-project intends to produce insights that can and should be taken up by professionals dealing with risks in various functions, and for that purpose more specialized channels are appropriate, starting with professional education.

4.1 Professional Education

In the coming decades, students of management, engineering, medicine, law, etc. will need to become "risk literate" all over the world. IRG-project will produce teaching material for this purpose, with special attention to the needs arising not only in developed, but also in developing countries.

The material will be built around the cases studied in IRG-project as well as further cases that are well documented in the literature. It will use the conceptual framework of socio-ecological systems, resilience, vulnerability, and global environmental change that is emerging out of the research unfolding in the IHDP framework and beyond. It will integrate this conceptual framework with quantitative tools like Bayesian risk analysis and complex system modeling.

The material will include a textbook complemented with web-based lectures, exercises, and supporting material⍰ that are regularly updated. It will be elaborated in cooperation with leading universities in developed countries, but also with major universities from developing countries. Researchers engaged in IRG-project will actively participate in teaching both in developed and developing countries.

One important aspect which will be taken into consideration is the need to elaborate all training and teaching materials in various languages, particularly due to the need of such products in all corners of the world. While initially all training material will be prepared in English language, efforts will be made to translate such material to languages such as Chinese, Spanish, and French in order to target audiences in all continents of the world.

In addition and taking into consideration the need to elaborate documents in a variety of formats, IRG project will launch an effort to increase the reusability of technical documentation through a novel approach to structure and format its content in a modular fashion that addresses both the information and learning needs of the target audiences. The novel approach aims at avoiding redundancy, improving consistency and strengthening collaboration in the elaboration of content.

4.2 Advanced Training

A related, but different task is to enable professionals dealing with risk management to maintain and improve their knowledge and skills in the course of their working life. This is especially important with regard to issues of integrated risk governance, as this is bound to be an area of massive change – sometimes to the better, but sometimes also for worse – in the 21th century. IRG-project will provide two kinds of products for advanced training in view of integrated risk governance. First, course material – both written and web-based – documenting recent advances in research. This shall be used by educational institutions, but also by government agencies, companies, and professional associations. Again, researchers engaged in IRG-project will actively participate in this kind of teaching, and they will do so both in developed and developing countries.

The second kind of material will be a case based database (CasDAT), suitable both for purposes of research and of advanced training. CasDAT will refer to various existing databases, like the disaster/risk databases of Munich Re and Swiss Re. It will differ from other databases by providing richer qualitative information, particularly on entry- and exit-transitions. It will also document debates about specific risk occurrences as well as about specific instruments of risk management. CasDAT will be key platform for the work performed in IRG-project, and it will be made accessible to users worldwide in an open source mode.

The database will be structured in such a way that it allows for analysis, particularly to find similarities and contrasts among countries and agencies in the way in which such agencies manage the Entry/Exit strategies in case of disasters; as well as changes over time and in the spatial extension related to the various levels at which risks and disasters are managed (local, municipal, provincial, national).

CasDAT shall be built with full exploitation of the advances of internet technology, taking advantage of growing capabilities of information gathering, sorting, and updating. Moreover, close collaboration with the on-going Disaster Reduction Hyperbase (DRH) work at Beijing Normal University is one of the defining features of IRG-projects since its very beginnings.

It will be natural to use these materials in workshops and summer schools organized within IRG-project. As several institutions currently involved in IRG-project have a well-established practice of advanced training, this will also provide an excellent opportunity to test the course material in the classroom before publishing it for use by others.

4.3 Managing Risk Occurences

As stated in the Mission Statement of IRG-project, the main goal of the project is to improve management in the face of risks that exceed current human coping capacity. In line with the scope of governance, such a goal is not only relevant for government agencies, but also for agencies from the private sector, including Non-Government Organizations, and even the mass media which also deal with both the entry and exit strategies in case of disasters.

In order to bridge the gap between science and practice, IRG-project will involve the targeted users of its research throughout the process. The more practical outcomes of research will be presented in terms of tools which will allow staff in government and non-government agencies to manage events more efficiently. These tools shall allow staff members to manage the information concerning relevant risks on a more coherent basis. This will involve external modules related to information management structures such as geographic information systems, commercial database software, and spatial imaging software (google earth for example).

However, the real success of IRG-project will be assessed in the context of those individuals and agencies that make use of its results and outputs when dealing with specific risk occurrences. IRG-project shall enable practitioners to recognize more easily and efficiently when a given risk exceeds given coping capacity, and it shall offer them examples and methods for how to deal with situations where this is the case. In particular, it shall help them to act fast enough in those critical moments where an entry transition can and must be shaped.

Besides supporting practitioners faced with single risk occurrence, IRG-project shall also provide know-how for the design and maintenance of early warning systems that are established in view of future occurrences. To this end, the concepts and methods developed by IRG-project should provide means to improve existing early warning systems (and the related entry strategies), as well as to design new early warning systems taking into account new findings.

In addition, IRG-project shall provide information to agencies in charge of response and recovery in case of disasters (exit strategies) which can be used to improve Standard Operating Procedures in order to ensure an efficient and timely response in case of a risk occurrence.

The Bayesian techniques that IRG-project will use in its modeling work are a key ingredient for further improving existing early warning technologies in many fields, ranging from environmental disasters to financial crises. Moreover, the understanding of entry-transitions that will be provided by our research shall help to address a key difficulty of many early warning systems: how to structure the communication process in such a way that a warning reaches its intended audience in a fast and effective way, avoiding panic while triggering decisive action.

4.4 Managing Unacceptable Risks

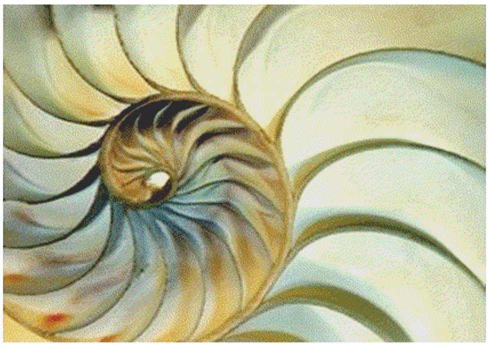
Integrated risk governance must deal with two very different kinds of risks: those that we have to accept as part of the human condition and those that we have to eliminate in order to achieve a sustainable development of humankind. All sorts of accidents, diseases, and crises are part of human life and must be accepted as such. The task in the face of such risks is to develop the capacity to cope with them in a responsible way, to enable people to avoid suffering as far as possible and to find meaning in coping with unavoidable suffering.

But in the past decades, more and more people have become aware or risks whose occurrence is unacceptable by any reasonable standard. They include nuclear war as well as the disasters caused by mass poverty, the dangers of massive sea-level rise as well as the possibility of future genocides. In the 21th century, integrated risk governance will be characterized not only by sound ways to handle the occurrences of those risks that we have to accept, but also by significant progress in avoiding those risks that we have to refuse, even if it will take a very long time to get rid of them.

The concept of persistent problems becomes essential here. Persistent problems are those whose ultimate causes have to be found in the previous development and implementation of an inadequate set of solutions to deal with them. The accumulation of side effects and structurally unresolved matters derived from multiple wrong decisions in different domains of action is the source or persistent problems.

The choice of one-dimensional solutions to problems that are inextricably interlinked together and that demand a more integrated approach can often result in the worsening of the initial conditions in which such problems originally emerged. When the set of issues at stake and their interactions are poorly defined, both on their social and ecological grounds, apparently 'exact' measures for action, as those often provided by technical fixes, may appeal to policy makers. However, new rebound effects may emerge and lead to even harder conditions to tackle in the next cycle of development. By studying entry and exit transitions in dealing – poorly – with persistent problems, IRG-Project can make a significant contribution to the management of unacceptable risks.

4.5 Learning to Learn



IRG-project will produce a broad range of publications including journal articles, research and policy briefs, as well as a website targeted at national and international communities of researchers and practitioners. It will do so to communicate specific findings, but also with a more subtle purpose in mind: enhancing the capability for further learning about integrated risk governance. A key contribution towards this goal will be the training and mentoring of a new generation of highly motivated researchers uniquely positioned to conduct multi-disciplinary research on the entry/exit transitions of various risks, and who appreciate the value of practical problem solving in the face of daunting risks.

These researchers need to be aware of the fact that risks are always embedded in particular structures of power and privilege. From the field of Integrated Sustainability Assessment (Rotmans, et al. 2008, Tabara et al. 2008) it has become clear that unless new tools and methods are developed which are specifically addressed to tackle changing status structures and related ways of agent transformation, there is little chance of progress toward a transition to sustainability.

Effective transitions in risk management often require changes in the distribution of critical resources in the relevant socio-ecological system.

Advantages and disadvantages of socio-ecological risks are distributed unevenly across agents and such inequality may often be the main reason that impedes the transformation of agents which can make a difference in taking adequate long-term structural risk remedial actions. Dealing with large-scale complex risks often is a matter of empowering specific agents in particular contexts of action so as to enable them to participate in the changing of existing risky conditions in which they have to operate.

Learning how to bring about such empowering is an on-going process that requires considerable modesty: only by acknowledging the limitations of our knowledge, understanding, and capabilities will there be a chance of overcoming these limitations where needed. Not the least merit of discussions about the precautionary principle in risk management is to raise awareness of the ignorance we are often trapped in (Stirling 2003).

If in the coming years IRG-project will enable researchers and practitioners in the arena of integrated risk governance to learn how to overcome again and again the barriers against further learning, it will have fulfilled its mission.

5 Implementation Strategy

In scientific research as elsewhere, truly creative work is based on small groups of people connected by rather loose organizational ties and a strong shared culture. In this spirit, we will implement our research strategy by fostering and gradually expanding such networks. The implementation strategy, therefore, has to be simple, and the organizational structure of IRG-project shall be lean.

In terms of current management concepts, IRG-project shall function as a process organization, with specific comparative case studies as well as modeling and other efforts being processes interacting with specific segments of the outside world, and central management operating as a support process at the service of research. We will start with a first process comparing two contrasting cases and supported by a minimal management structure, add further research processes step by step and strengthening the management structure as the need arises.

The interface with practicioners shall be established at the level of the different research processes, not as an add-on run separately. This places the burden of developing a shared language among researchers and practicioners on the researchers themselves – not an easy task, but a powerhouse of creativity in a field like integrated risk governance.

In the same spirit, the interface with other international (and national) research programs shall be firmly rooted in the relevant research processes. Joint publications as well as long-lasting involvement in practical operations are yardsticks by which the effectiveness of these interfaces can be assessed.

We see the people involved in coordinating IRG-project as supporting the research done by themselves and by others, not as managing it in a highly directive manner. IRG-project shall form a space for research inspired by the ideas outlined in this science plan, create and maintain a culture of high-quality research, and patiently work towards the surprising insights that will provide first elements for answering our overarching question – and we reiterate it: *How can risk governance be improved and synergies be created at multiple governance levels, up to the point where risks that currently leave most people profoundly helpless become challenges that can be tackled in a responsible way?*

5.1 Twin Program Offices

The daily management of IRG-Project will be conducted in parallel by the twin program offices located in Beijing, China and Potsdam, Germany. Beijing Normal University and the Potsdam Institute of Climate Impact research will host the twin International Program Offices (IPOs). Both offices will receive input from the IRG-Project Science Advisory Committee and oversee the overall management and operations of IRG-Project.

The roles of the twin IPOs are

1) to assist the IRG-Project Scientific Advisory Group to implement IRG-Project efficiently with considerable effort made to assure good communications at the operational level among the different research groups,

2) to maintain uniformity and standardization of database, models, tools, and procedures used on all platforms and in all research groups,

3) to foster close cooperation with other international research programs.

There are a large number of international programs with scientific goals that are complementary to those of IRG-Project and where collaboration would be advantageous. They include ICSU, ISDR, IRGC. IRG-Project IPOs will work with those potential collaborators to explore the possibility of cosponsoring workshops, sharing of technical expertise, technologies and equipment, or developing specific research experiments. IPOs will also explore the opportunity to make significant contributions to other international programs in policy application and training decision makers. Other programs might enhance IRG-Project's research capabilities by contributing specialized tools such as models for natural hazards, or providing critical data.

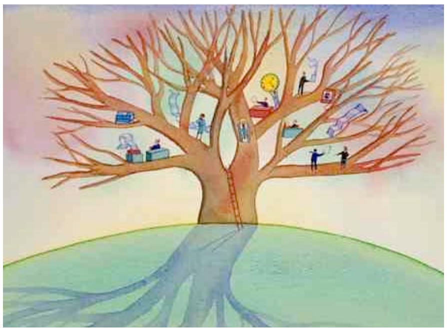
5.2 Budget

IRG-Project provides a platform for researchers, policy makers and business decision makers to exchange ideas, data, knowledge, experience. IRG-Project will play a role for coordinating, organizing and moderating research efforts to deal with issues related with very large scale disasters. We expect the overall activities of IRG-project to start with a total budget of about 500'000 $ in the first year, gradually expanding to the scale of about 2 million $ in the tenth year.

IRG-project will apply for funds on a project basis with national and international foundations, with government institutions, private businesses, and donors. When cooperating with businesses, IRG-project will explicitly include NGOs in the relevant activities, so as to have a system of checks and balances in place in order to guarantee both its impartiality and its credibility.

The members of IRG-Project will provide their own resources, helping to finance the twin IPOs if they are in a position to do so. The twin International Program Offices will submit their annual budgets for daily operations to the management of the institutions hosting them. The funds of the IPO in Beijing for the next 5 years have been secured and provided by the Ministry of Sciences and Technology, the Ministry of Education and the National Natural Science Foundation of China. The IPO in Potsdam is operational and shall be further funded on a project basis.

5.3 Communication



The main activities of IRG-project will consist in doing research, and doing it well. Communication within single research groups will be based on intensive face-to-face contacts, advanced computer technology (e.g. archiving systems with versions and sub-versions), and the standard scientific materials.

Between research groups, communication will be mainly internet based. IRG-Project will encourage its members to hold local, regional, and international workshops so that researchers can have face-to-face discussions on emergent issues. And it will also encourage its members to continuously improve internal memos and documents so that they become important elements of the writing of working papers and eventually publications in the open literature.

Besides the outreach activities that are an integral part of the single research processes, IRG-Project will conduct additional outreach activities based on its website (update monthly), newsletters (initially semi-annual), books, research papers, policy recommendations, etc. IRG-Project will hold its Scientific Advisory Committee meeting annually and its science conference every two years.

5.4 Timelines

How can one look for an insight without knowing it? The paradox of inquiry led Socrates to consider gaining an insight as a kind of remembering. It leads us to imagine the development of IRG-project as a journey of discovery: the starting point is well defined, the initial equipment is given, the first steps can be indicated, and they are consciously planned so as to lead us into a surprising terrain that will enable and force us to change our plans. What we will not change is the focus on discoveries that will help us addressing our overarching question and its different elements.

This requires the willingness to invest seveeral years exploring the terrain, being satisfied with small, if robust findings. In these first years we will perform no more than 5 case studies, with a strong emphasis on the comparison between different cases. In parallel, we will explore conceptual issues related to entry- and exit-transitions. After three to five years, we expect to be able to make a first major discovery, perhaps of one key entry mechanism.

From there, again over a period of several years, we expect to proceed towards a more systematic understanding of those transitions, including their relevance for practicioners. And then, as far as we can see from today, we may even become able to spell out the fundamental logic of the transitions, and thereby deliver a key for developing integrative risk governance of the kind required for truly sustainable development.

6 Acknowledgment

We are profoundly grateful to a series of institutions and people whose initiatives and support made IRG-Project possible in the first place. They include:

The Ministry of Science and Technology (MOST) of the People's Republic of China; Vice-Minister Liu Yanhua of MOST;

The International Program for the Study of Global Environmental Change (IHDP); Oran Young (chair), Andreas Rechkemmer (executive director), Falk Schmidt (officer) of IHDP;

The Integrated Risk Government Council (IRGC);

The International Disaster and Risk Conference (IDRC);

Beijing Normal University (BNU);

The Potsdam Institute for Climate Impact Research (PIK).

Special thanks for inspiring conversations go to Nicole Dewaendre, Hans Föllmer, Mickey Glantz, Jill Jäger, Jay Kadane, Rupert Klein, Wolfgang Kröger, Ragnar Löfstedt, Granger Morgan, Christian Mumenthaler, Joachim Oechslin, Elinor Ostrom, Ortwin Renn, Gene Rosa, Alois Rust, Teddy Seidenfeld, Sander van der Leeuw and many more.

7 References

Adams, W.M., Jeanrenaud, S.J. (2008) Transition to Sustainability: Towards a Humane and Diverse World. IUCN, Gland, Switzerland.

Alexander, D. (2000) Confronting Catastrophe - New Perspectives on Natural Disasters. Oxford University Press, Oxford.

Amendola, A., Linnerooth-Bayer, J., Okada, N., Shi, P. (2008) Towards Integrated Disaster Risk Management: Case Studies And Trends From Asia. Natural Hazards, 44, Special Issue.

Beck, U. (1992) Risk Society: Towards a New Modernity. Sage, New Delhi.

Berkes, F. and Folke, C. (eds.) (1998) Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge UP, Cambridge.

Bernstein, P.L. (1996) Against the Gods: The Remarkable Story of Risk. Wiley, New York.

Blaikie, P., Cannon, T., Davis, I., Wisner, B. (1994) At Risk: Natural Hazards. People’s Vulnerability, and Disasters. Routledge, London.

BMBF (2004) Aufbau eines Tsunami-Fruehwarnsystems im Indischen Ozean. Der deutsch-indonesische Beitrag. BMBF, Bonn.Bouchaud, J.P., Potters, M. (2000) Theory of Financial Risks: From Statistical Physics to Risk Management. Cambridge UP, Cambridge.

Bunting, C., Renn, O., Florin, M.V., Cantor, R. (2007) The IRGC risk governance framework. John Liner Review 21, 7-26.

Burton, I., Kates, R.W., White, G.F. (1995) The Environment as Hazard. The Guilford Press, New York, NY.

Bussiere, M., Fratzscher, M. (2006) Towards a New Early Warning System of Financial Crises. Journal of International Money and Finance, 25, 953-973.

Chabay, I. (2004) Design for Learning: Product Design and Engineering for a Knowledge-Based Society. Proceedings of the International Engineering and Product Design Education Conference, Delft.

Crawford, S.E.S., Ostrom, E. (1995) A Grammar of Institutions. The American Political Science Review, 89, 582-600.

Dlugolecki, A.F. (2000) Climate Change and the Insurance Industry. The Geneva Papers on Risk and Insurance - Issues and Practice, 25, 582-601.

Elzen, B., Geels, F., Green, K. (eds.). System Innovation and the Transition to Sustainability: Theory, Evidence and Policy. Edward Elgar, Cheltenham, UK.

Emery, F. E., Trist, E.L. (1965) The causal texture of organizational environments. Human Relations, 18, 21-32

Gallopín, G.C. (1991) Human Dimensions of Global Change: Linking the Global and the Local Processes. International Social Science Journal, 130, 707–718.

Gardner, M.R., Ashby, W.R. (1970) Connectance of Large Dynamic (Cybernetic) Systems: Critical Values for Stability, Nature, 228, 784.

Glaser, B.G., Strauss A. (1967) The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine, Chicago.

Gintis, H. (2007) The Dynamics of General Economic Equilibrium. The Economic Journal, 117, 1280-1309.

Hacking, I. (2007) The Emergence of Probability: A Philosophical Study of Early Ideas about Probability, Induction and Statistical Inference. Cambridge UP, Cambridge.

Haimes, Y.Y. (2004) Risk Modeling, Assessment, and Management. Wiley, New York NY.

Hallegatte, S. (2008) An Adaptive Regional Input-Output Model and its Application to the Assessment of the Economic Costs of Katrina. Risk Analysis 28, 779-799.

Hardin, G. (1968) The Tragedy of the Commons. Science, 162, 1243-1248.

Held, D., McGrew, A., Goldblatt, D., Perraton, J. (1999) Global Transformations: Politics, Economics and Culture. Polity Press, Cambridge.

Hendricks, V.F., Pedersen, S.A., Jørgensen, K.F. (eds) (2001) Probability Theory: Philosophy, Recent History, and Relations to Science. Kluwer, Dordrecht.

Herman A.; Kumar V. B.; Arkin P. A.; Kousky J. V. (1997) Objectively determined 10-day African rainfall estimates created for famine early warning systems. International Journal of Remote Sensing, 18, 2147-2159.

ICSU (2008) A Science Plan for Integrated Research on Disaster Risk: Addressing the challenge of natural and human-induced environmental hazards. ICSU, Paris.

ISDR (2004) Living with Risk – A global review of disaster reduction initiatives (2 vols). ISDR, United Nations, Geneva.

Jaeger, C.C. Krause, J., Haas, A., Klein, R., Hasselmann, K. (2008) A Method for Computing the Fraction of Attributable Risk Related to Climate Damages. Risk Analysis, 28, 815-823.

Jaeger, C.C. (1994) Taming the Dragon. Transforming Economic Institutions in the Face of Global Change. Gordon and Breach Science Publishers, Yverdon.

Jaeger, C.C., Renn, O., Rosa, E.A., Webler, T. (2001) Risk, Uncertainty, and Rational Action. Earthscan, London.

Jasanoff, S. (1986) Risk Management and Political Culture. Russell Sage, New York.

Jorion (1997) Value at risk: the new benchmark for controlling market risk. 1997 McGraw-Hill, New York, NY.

Kahneman, D. (2003) Maps of Bounded Rationality: A Perspective on Intuitive Judgment and Choice, in: Frängsmyr, T. (ed) Les Prix Nobel 2002, Almquist & Wiksell International, Stockholm.

Kasperson, R.E., Kasperson, J.X. (1996) The Social Amplification and Attenuation of Risk, Annals of the American Academy of Political and Social Sciences 545, 95-105.

Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., Ratick, S. (1988) The social amplifications of risk. A conceptual framework. Risk Analysis 8, 177-187.

Kirman, a. (1992) Whom or what does the representative individual represent? Journal of Economic Perspectives 6, 117-136.

Lahsen, M.H. (2007) Anthropology and the Trouble of Risk Society. Anthropology News, Dec. '07, 9-10.

Linnerooth-Bayer, J., Mechler, R, Pflug, G. (2005) Refocusing Disaster Aid, Science 309, 1044-1046.

Lofstedt, R., Renn, O. (1997) The Brent Spar Controversy: An Example of Risk Communication Gone Wrong. Risk Analysis, 17, 131–136.

Machina, M. (1987) Choice under Uncertainty: Problems Solved and Unsolved. Journal of Economic Perspectives, 1, 121-154.

May, R.M. (1973) Stability and Complexity in Model Ecosystems. Princeton UP, Princeton, NJ.

Mileti D.S. (1999) Disasters by Design. A Reassessment of Natural Hazards in the United States. National Academy Press, Washington D.C.

Morgan, M.G., Fischhoff, B., Bostrom, A., Atman, C.J. (2002) Risk Communication: A Mental Models Approach. Cambridge UP, Boston, MA.

NRC (National Research Council of the National Academies) (1999) Our Common Journey: A Transition Toward Sustainability. National Academy Press, Washington, D.C.

NRC (National Research Council of the National Academies) (2006) Facing Hazards and Disasters: Understanding Human Dimensions. The National Academies Press, Washington DC.

Okada, N. (2004) Urban Diagnosis and Integrated Disaster Risk Management. Journal of Natural Disaster Science, 26, 49-54.

OECD (2003) Report on Emerging (Systemic) Risks in the 21st Century. OECD, Paris.

Ostrom, E. (2005) Understanding Institutional Diversity, Princeton UP, Princeton, NJ.

Perrow, C. (2007) The Next Catastrophe: Reducing our Vulnerabilities to Natural, Industrial and Terrorist Disasters. Princeton, Princeton UP.

Pidgeon, N., Kasperson, R.K., Slovic, P. (eds) (2003) The Social Amplification of Risk. Cambridge UP, Cambridge.

Raskin, P., Banuri, T., Gallopín, G., Gutman, P., Hammond, A., Kates, R., Swart, R. (2002) The Great Transition: The Promise and the Lure of the Times Ahead. Tellus Institute, Boston, MA.

Renn, O. (2008) Risk Governance: Coping with Uncertainty in a Complex World. Earthscan, London.

Sagan, S.D. (1993) The Limits of Safety: Organizations, Accidents, and Nuclear Weapons. Princeton UP, Princeton, NJ.

Dakos, V., Scheffer, M., van Nes, E.H., Brovkin, V., Petoukhov, V., Held, H. (2008) Slowing down reveals climatic tipping points, PNAS 105, 14308-14312.

Scheuren, J-M., le Polain de Waroux, O., Below, R., Guha-Sapir, D., Ponserre, S. (2008) Annual Disaster Statistical Review: The Numbers and Trends 2007. Center for Research on the Epidemiology of Disasters (CRED). Melin (Belgium).

Sen, A., Drèze, J. H. (1995) The Political Economy of Hunger, Oxford, Clarendon Press.

Shi, P. (1991) On the Theory of Disaster Research and its Practice, Journal of Nanjing University, 11, 37-42.

Shi P. (ed) 2003, Atlas of Natural Disaster System of China, China Science Publishing Group, Beijing.

Shi P. (2005) Theory and practice of disaster system research in a fourth time, Journal of Natural Disasters. 14, 1-7.

Shi, P., Du, J., Ye, T., et al, (2006a) Strengthen Integrated Disaster Risk Research and Enhance Capacity of Production & Economic Sector for Disaster Risks, Journal of Natural Disasters, 15, 1-6 (In Chinese).

Shi, P., Li, N., Liu, Q. et al (2006b) A Discovery Approach for Development and Disaster Reduction Coordination, Journal of Natural Disasters, 15, 1-8 (In Chinese).

Shi, P., Jianjun, W., Jing, L., Juan, D. (2005a) Understanding of Integrated Regional Disaster Risk Reduction Mode. Asian Conference on Disaster Reduction. 9, 27-29, Beijing.

Shi, P., Guo, W., Li, B., et al (2005b) Model for Disaster Reduction and Sustainable Development, Journal of Natural Disasters, 14, 1-7 (In Chinese).

Shi, P., Wang, J., Yang, M., Chen, J., Pan, Y., Wang, P., Fang, W., Zhou, W., Wan, Y., Yuan, Y., Xu, X. (2000) Understanding of Natural Disaster Databases Design and Compilation of Digital Atlas of Natural Disasters in China. Geographic Information Sciences, 6, 140-147.

Shiller, R.J. (2004) The New Financial Order: Risk in the 21st Century. Princeton UP, Princeton, NJ.

Shultz, G.P., Perry, W.J., Kissinger, H., Nunn, S. (2008) Toward a Nuclear-Free World. The Wall Street Journal, January 15.

Stilgoe, J., Wilsdon, J. Wynne, B. (2005) The Public Value of Science. Or how to ensure that science really matters. Demos, London.

Stirling, A. (2003) Risk, uncertainty and precaution: Some instrumental implications from the social Sciences. In: Berkhout, F., Leach, M. and Scoones, I. (eds.), Negotiating Change. Edward Elgar, London.

The World Bank (2006) Hazards of Nature, Risks to Development. An IEG Evaluation of World Bank Assistance for Natural Disasters. The World Bank, Washington, D.C.

Turner, B. L. II., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., Schiller, A. (2003) A framework for vulnerability analysis in sustainability science. PNAS, 100, 8074–79.

UNDP (2004) Reducing Disaster Risk: A Challenge for Development. United Nations, New York, NY.

Villagrán de León, J.C. (2006) Vulnerability, a conceptual and methodological review. UNU-EHS, No. 4.

WBGU (German Advisory Council on Global Change) (1998) Strategies for Managing Global Environmental Risks. Annual Report. WBGU, Berlin.

Weick, K.E., Sutcliffe, K.M. (2001) Managing the Unexpected: Assuring High Performance in an Age of Complexity. Assuring High Performance in an Age of Complexity. Wiley, New York, NY.

Wisner, B., Blaikie, P., Cannon, T., Davis, I. (2003) At Risk. Routledge, New York.

Yin, R. K. (1984) Case Study Research. Design and Methods. Sage, Newbury Park, CA.

Yoon, S.-M., Choi, J.S., Lee, C.C., Yum, M.-K., Kim, K. (2006) Phase transition of dynamical herd behaviors for Yen–Dollar exchange rates. Physica A: Statistical Mechanics and its Applications, 359, 563-568.

Young, H.P. (1993) The Evolution of Conventions. Econometrica, 61, 57-84.

Young, O.R., Berkhout, F., Gallopin, G.C., Janssen, M.A., Ostrom, E., Sander van der Leeuw, S. (2006) The globalization of socio-ecological systems: An agenda for scientific research. Global Environmental Change, 16, 304–316.

Zha, H., Pan, Z., Thwaites, H., Addison, A.C., Forte, M. (2006) Interactive Technologies and Sociotechnical Systems. Springer, New York.

8 Appendix

8.1 Milestones of the Science Plan Preparation

October 2006: IRG-Project was initiated by CNC-IHDP during the ESSP Beijing Conference;

March 2007: At the IHDP SSC meeting in Brazil, CNC-IHDP made a formal proposal that IRG-Project be considered as a potential IHDP core project;

September 2007: IHDP formed a Scientific Planning Committee (SPC) for a core project on Integrated Risk Governance, and the Committee held its first meeting in Beijing, China;

February 2008: The IRG-Project Pilot Research Plan was drafted in Beijing, China;

June 2008: An IRG-Project special workshop was held by the SPC in Santa Barbara, USA;

August 2008: The IRG-Project Pilot Research Plan was finalized in Potsdam, Germany;

October 2008: The IRG-Project Pilot Research Plan was presented at and approved by the IHDP SSC in New Delhi, India; the Pilot Research Plan was published on the IRG-Project website;

November/December 2008: Comments on the Pilot Research Plan were collected from SPC members and further interested scholars;

January, 2009: The IRG-Project Science Plan was drafted in Beijing, China;

February, 2009: The IRG-Project Science Plan was finalized in Potsdam, Germany.

8.2 The Scientific Planning Committee

NAME	ORGANIZATION

(Names marked with an asterix indicate supporting members of the writing team.)

Dr. Sálvano Briceño	International Strategy for Disaster Reduction (ISDR)
Prof. Ilan Sandor Chabay	Chalmers University of Technology
Prof. Kanchan Chopra	Institute of Economic Growth, New Delhi

Prof. Dr. Dong Wenjie*	Director-General of National Climate Center, Beijing
Dr. Fang Weihua*	Beijing Normal University (BNU)
Prof. Gilberto C. Gallopín	Economic Commission for Latin America and the Caribbean
Dr. Armin Haas*	Potsdam Institute for Climate Impact Research, ECF
MSc. Guoyi Han	Stockholm Environment Institute (SEI)
MSc. Jennifer F. Helgeson*	National Institute of Standards and Technology, MD
Prof. Carlo Jaeger (Co-Chair)	Potsdam Institute for Climate Impact Research, ECF
Dr. Patricia G. Kameri-Mbote	International Environmental Law Research Centre
Prof. Roger E. Kasperson	Clark University
Dr. Myanna Lahsen*	IGBP Regional Support Office Brazil
Dr. Louis Philip Lebel	Chiang Mai University, Thailand
Prof. Li Ning	Beijing Normal University
Prof. Yanhua Liu	Chinese Ministry of Science and Technology / CNC-IHDP
Prof. Gordon McBean	University of Western Ontario
Prof. Granger Morgan	Carnegie Mellon University
Dr. Esther Mwangi	Harvard, JFK School of Government
Prof. Norio Okada	Disaster Prevention Research Institute, Kyoto University
Dr. Andreas Rechkemmer	IHDP Bonn (Executive Director)
Prof. Ortwin Renn	University of Stuttgart
Falk Schmidt	IHDP Bonn (Academic Officer)
Prof. Shi Peijung (Co-Chair)	Beijing Normal University (BNU)
Prof. Andrew Stirling	University of Sussex, The Sussex Energy Group
Annika Strate*, M.A.	Potsdam Institute for Climate Impact Research, ECF

Dr. Joan David Tábara*	ICTA – Universitat Autonoma de Barcelona.
Dr. Juan Carlos Villagrán de León*	UNU – Institute for Environment and Human Security
Dr. Ye Qian	University of Colorado
Prof. Oran Young	Chair of IHDP, University of
California – Santa Barbara	