Report

Risk Governance Deficits

An analysis and illustration of the most common deficits in risk governance

international risk governance council

Abbreviations used in the text:

AIDS	Acquired Immune Deficiency Syndrome
BSE	Bovine Spongiform Encephalopathy
CFC	Chlorofluorocarbon
CJD	Creutzfeldt-Jacob Disease
CO_2	Carbon Dioxide
DH	Department of Health (UK)
DHS	Department of Homeland Security (US)
DWD	Drinking Water Directive (EU)
EMF	Electromagnetic Field
EPA	Environmental Protection Agency (US)
EU	European Union
FDA	Food and Drug Administration (US)
FEMA	Federal Emergency Management Agency (US)
FQPA	Food Quality Protection Act (US)
GM	Genetically Modified
GMO	Genetically Modified Organism
GURT	Genetic-Use Restriction Technology
HIV	Human Immunodeficiency Virus
IARC	International Agency for Research on Cancer
IRGC	International Risk Governance Council
ITQ	Individual Transferable Quota
LLRW	Low-Level Radioactive Waste
MAFF	Ministry of Agriculture, Fisheries and Food (UK)
MMR	Measles, Mumps and Rubella Vaccine
MTBE	Methyl Tertiary-Butyl Ether
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Cooperation and Development
OSHA	Occupational Health and Safety Administration (US)
PES	Payment for Environmental Services
REDD	The Reduced Emissions from Deforestation and Forest Degradation scheme
RIA	Regulatory Impact Assessment
SARS	Severe Acute Respiratory Syndrome
SBO	Specified Bovine Offal
SVS	State Veterinary Service (UK)
TSO	Transmission Service Operator
TURFs	Territorial Use Rights in Fishing
UCTE	Union for the Coordination of Transmission of Electricity
UK	United Kingdom of Great Britain and Northern Ireland
UN	United Nations
UNESCO	United Nations Educational Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
vCJD	Variant Creutzfeldt-Jacob Disease
WHO	World Health Organization

Cover picture:
Satellite image of Hurricane Katrina approaching the Gulf Coast of the United States

ISBN 978-2-9700631-9-3

Preface

The International Risk Governance Council (IRGC) is an independent organisation whose purpose is to aid in the understanding and management of emerging global risks. It does so by developing concepts of risk governance, anticipating major risk issues and providing risk governance policy recommendations for key decision-makers.

IRGC defnes **risk governance** as the identifcation, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated, and how and by whom management decisions are taken and implemented.

One of IRGC's tasks is the improvement of concepts and tools for the understanding and practice of risk governance itself. Good risk governance should, IRGC upholds, enable societies to benefit from change while minimising its negative consequences.

This report on defcits in the risk governance process is a continuation of the development of IRGC's approach to risk governance. Central to this approach is the IRGC Risk Governance Framework, intended to help policymakers, regulators and risk managers in industry and elsewhere both understand the concept of risk governance and apply it to their handling of risks. A detailed description of IRGC's Risk Governance Framework was published in IRGC's White Paper "Risk Governance –Towards an Integrative Framework" in 2005 [IRGC, 2005].

IRGC's approach emphasises that risk governance is context-specifc. A range of factors – including the nature of the risk itself, how different governments assess and manage risks, and a society's level of acceptance or aversion to risk, among others – means that there can be no single risk governance process. The framework is therefore deliberately intended to be used fexibly.

The framework is central to IRGC's work – from it stems the distinction made in this report between understanding and managing risks. However, in this report on risk governance defcits, IRGC is not assuming that readers are familiar with the framework. All explanations in this report are hence self-explanatory and do not presume prior knowledge of the IRGC framework or terminology.

In developing recommendations for improving the risk governance of such issues as nanotechnology, bioenergy, critical infrastructures, and carbon capture and storage, it became clear to IRGC that many defcits are common to several risk types and organisations; they recur, often with serious health, environmental and economic consequences, across different organisational types and in the context of different risks and cultures.

Identifying defcits in existing risk governance structures and processes is now another signifcant element of IRGC's methodology. The concept of risk governance defcits – which can be either defciencies or failures within risk governance processes or structures – complements the use of the framework itself with an analytical tool designed to identify weak spots in how risks are assessed, evaluated and managed. These weak spots are the focus of this report.

The purpose of this report is to introduce to managers in government and industry the concept of risk governance defcits, to list and describe the most common defcits, to explain how they can occur, to illustrate them and their consequences, and to provide a catalyst for their correction.

Summary

IRGC defnes risk governance defcits as defciencies (where elements are lacking) or failures (where actions are not taken or prove unsuccessful) in risk governance structures and processes. They hinder a fair and effcient risk governance process.

The defcits described by IRGC have recurred over time and have affected risk governance in many types of private and public organisations, and for different types of risks. While defcits may be relevant for both simple and systemic risks, in this report we focus on the latter. This is because systemic risks – defned as those risks that affect the functionality of systems upon which society depends and that have impacts beyond their geographic and sector origins – provide a greater challenge for risk governance and thus greater scope for the occurrence of defcits.

The potential consequences of risk governance defcits can be severe in terms of human life, health, the environment, technology, fnancial systems and the economy as well as social and political institutions. There may be a failure to trigger necessary action, which may be costly in terms of lives, property or assets lost; or the complete opposite – an over-reaction or ineffcient action which is costly in terms of wasted resources. Consequences of defcits can also discourage the development of new technologies, as they can lead to a suffocation of innovation (through over-zealous regulation) or to unintended consequences (through failing to account for secondary impacts). Loss of public trust in those responsible for assessing and managing risk or an unfair (or inequitable) distribution of risks and benefts are other possible adverse outcomes.

By identifying and describing these important defcits, this report aims to help risk decision-makers in government and industry understand both the *causes* of defcits in risk governance processes and their capacity to aggravate the adverse *impacts* of a risk. With this understanding, it is hoped that risk practitioners will be able to identify and take steps to remedy signifcant defcits in the risk governance structures and processes in which they play a part, including those that may be found within their own organisations.

Although presented in this report as distinct phenomena, with their respective causes, drivers, properties and effects, defcits can be inter-related (for example, a defcit in risk assessment may increase the chances of another, linked defcit occurring during the management phase) and a single risk issue may be subject to multiple defcits.

As with the design of its risk governance framework, IRGC has grouped the defcits to refect the distinction between assessing risk and managing risk. Those in the assessment sphere (cluster A) relate to the collection and development of knowledge, understanding and evaluation of risks. Those in the management sphere (cluster B) concern the acceptance of responsibility and the taking of action in order to reduce, mitigate or avoid the risk. Each defcit is illustrated by examples from the risk governance of past or current risk issues – for example, the outbreak of “mad cow disease”, Bovine Spongiform Encephalopathy (BSE), in the United Kingdom (UK), Hurricane Katrina, fsheries depletion or genetically modifed crops in Europe –in order to demonstrate the severity and variety of material and immaterial impacts they can have.

Cluster A: Assessing and understanding risks

Risk governance defcits can occur during risk assessment. Such defcits arise when there is a defciency of either scientifc knowledge or of knowledge about the values, interests and perceptions of individuals and societies. They can also be caused by problems within the processes by which data is collected, analysed and communicated as knowledge, or result from the complexity and interdependencies within the system at risk. Complexity, uncertainty and ambiguity are thus key challenges for risk assessment and underlie all of the defcits in cluster A.

IRGC has identifed 10 defcits in risk assessment.

The first few deficits address difficulties involving the gathering and interpreting of knowledge about risks and perceptions of risks:

- (A1) the failure to detect early warnings of risk because of erroneous signals, misinterpretation of information or simply not enough information being gathered;
- (A2) the lack of adequate factual knowledge for robust risk assessment because of existing gaps in scientific knowledge or failure to either source existing information or appreciate its associated uncertainty; and
- (A3) the omission of knowledge related to stakeholder risk perceptions and concerns.

The following three deficits have to do with disputed, or potentially biased or subjective, knowledge, and have the effect of making it difficult to judge whether a risk needs specific attention or action. They comprise:

- (A4) the failure to consult the relevant stakeholders, as their involvement can improve the information input and the legitimacy of the risk assessment process (provided that interests and bias are carefully managed);
- (A5) the failure to properly evaluate a risk as being acceptable or unacceptable to society; and
- (A6) the misrepresentation of information about risk, whereby biased, selective or incomplete knowledge is used during, or communicated after, risk assessment, either intentionally or unintentionally.

A further three deficits focus on knowledge related to systems and their complexity:

- (A7) a failure to understand how the components of a complex system interact or how the system behaves as a whole, thus a failure to assess the multiple dimensions of a risk and its potential consequences;
- (A8) a failure to recognise fast or fundamental changes to a system, which can cause new risks to emerge or old ones to change; and
- (A9) the inappropriate use of formal models as a way to create and understand knowledge about complex systems (over- and under-reliance on models can be equally problematic).

The final deficit in cluster A addresses how knowledge and understanding are never complete or adequate. At the core of this deficit (A10) is the acknowledgement that understanding and assessing risks is not a neat, controllable process that can be successfully completed by following a checklist. Rather, this deficit is about assessing potential surprises. It occurs when risk assessors or decision-makers fail to overcome cognitive barriers to imagining that events outside expected paradigms are possible.

Cluster B: Managing risks

Risk governance deficits can also occur during risk management. These deficits concern responsibilities and actions for actually managing the risk and can be sub-grouped as relating to: a) the preparation and decision process for risk management strategies and policies; b) formulating responses and taking actions; and c) the organisational capacities for implementing risk management decisions and monitoring their impacts.

Those deficits related to the preparation and decision process for risk management strategies and policies derive from failures or deficiencies on the part of risk decision-makers to set goals and thoroughly evaluate the available options and their potential consequences. They are:

- (B2) a failure to design effective risk management strategies. Such failure may result from objectives, tools or implementation plans being ill-defined or absent;
- (B3) a failure to consider all reasonable, available options before deciding how to proceed;
- (B4) not conducting appropriate analyses to assess the costs and benefits (efficiency) of various options and how these are distributed (equity);
- (B6) a failure to anticipate the consequences, particularly negative side effects, of a risk management decision, and to adequately monitor and react to the outcomes;
- (B7) an inability to reconcile the time-frame of the risk issue (which may have far-off consequences and require a long-term perspective) with decision-making pressures and incentives (which may prioritise visible, short-term results or cost

reductions); and, lastly,

- (B8) a failure to adequately balance transparency and confidentiality during the decision-making process, which can have implications for stakeholder trust or for security.

Each of these deficits has the capacity to derail the risk management process – even if other deficits are avoided. For example, no matter how successfully an organisation coordinates its resources to quickly implement a strategy or enforce a regulation, the results will be inadequate if the original strategy or regulation was flawed from the beginning.

The deficits which relate to formulating responses, resolving conflicts and deciding to act derive from an inability on the part of the risk manager to identify the most appropriate response given the context or even to properly understand the context of the risk issue, which inevitably must guide the response. These deficits are:

- (B1) a failure to respond adequately to early warnings of risk, which could mean either under- or over-reacting to warnings;
- (B11) a failure to deal with the complex nature of commons problems, resulting in inappropriate or inadequate decisions to mitigate commons-related risks (e.g., risks to the atmosphere or oceans);
- (B12) a failure to resolve conflicts where different pathways to resolution may be required in consideration of the nature of the conflict and of different stakeholder interests and values; and
- (B13) insufficient flexibility or capacity to respond adequately to unexpected events because of bad planning, inflexible mindsets and response structures, or an inability to think creatively and innovate when necessary.

Finally, there are the deficits related to organisational capacities for responding or monitoring. These occur because of shortcomings in terms of resources, willpower or coordination:

- (B5) a failure to implement risk management strategies or policies and to enforce them;
- (B9) a lack of adequate organisational capacity (assets, skills and capabilities) and/or of a suitable culture (one that recognises the value of risk management) for ensuring managerial effectiveness when dealing with risks; and, finally,
- (B10) a failure of the multiple departments or organisations responsible for a risk's management to act individually but cohesively, or of one entity to deal with several risks.

Risk governance deficits: a real-world example

The emergence of BSE in the UK and the early handling of the epidemic in British cattle was certainly an example of inadequate risk governance. This case is used in the report to illustrate several of the above deficits from both the assessment and management clusters.

BSE is a neurodegenerative disease affecting cattle, transmissible to humans via consumption of infected beef. As a novel disease in 1986, it gave no obvious early warning signals of its emergence; cattle were sick, but there was no clear cause. Additionally, risk assessors did not possess adequate scientific knowledge of its epidemiology or pathology to confidently evaluate what sort of risk it posed to animal or human health (A2). Expert groups convened to study the disease and to advise on whether BSE could have implications for human health could only conclude that negative implications were "unlikely". However, the uncertainty associated with the available knowledge meant that public health risks could not be ruled out. Nevertheless, authorities did not take into account this uncertainty and repeatedly assured the public that British beef was safe to eat. Even as evidence of BSE's transmissibility to other species (such as cats and pigs) began to mount, authorities gave the public the impression that BSE was not transmissible to humans. The importance and implications of precautionary public health measures taken by the government were also downplayed in the public domain. These actions constituted a misrepresentation of information about the true risks of BSE (A6) and contributed to what was, on the whole, a serious failure in risk communication. The government's efforts to reassure the public that there was no risk from BSE actually ended up creating more risk and contributing to the scale of the negative economic and social consequences.

With regard to the precautionary regulations that were eventually put in place, here the dominant deficit was the failure to implement and enforce risk management measures (B5). Two of the most important regulations introduced during the BSE epidemic – the ban on feeding ruminant animals meat and bone meal made from animal carcasses, and the ban on incorporating specified bovine offal (SBO) into human food – were neither implemented nor enforced as effectively as they could have been. Concern for the economic health of industry led to a five week delay in the implementation of the ruminant feed ban and to very lax enforcement of the SBO ban.

Dispersed responsibilities (B10) also caused a number of problems throughout the handling of the crisis. Communication and collaboration were slow or non-existent between the Department of Health (responsible for public health) and the Ministry of Agriculture, Fisheries and Foods (MAFF, responsible for animal health and agricultural interests). Internal divisions and contradictions within MAFF further complicated matters.

Overall, dealing with BSE and its consequences is estimated to have cost the UK government £4.4 billion by 2001 and (to September 2009) 165 people had died from the human form of the disease, Variant Creutzfeldt-Jakob Disease (vCJD).

BSE and the other illustrations used in this report demonstrate the impact of risk governance deficits on past risk issues. They also show how the underlying concept of deficits reflects the interactive process between risk assessment and management, as well as that between risk generators and those affected by it.

Overall, this report can be used by organisations as a checklist to, first, evaluate the risk governance processes of which they are a part and, then, prioritise those which are most in need of improvement.

IRGC will provide further guidance on acting on the concepts described in this report in a policy brief to be published in late 2009.

I Introduction

Risk governance deficits are deficiencies or failures in the identification, assessment, management or communication of risks, which constrain the overall effectiveness of the risk governance process. Understanding how deficits arise, what their consequences can be and how their potential negative impact can be minimised is a useful starting point for dealing with emerging risks as well as for revising approaches to more familiar, persistent risks.

The aim of this document is to provide guidance on identifying risk governance deficits and to improve understanding of the causes of failures in risk governance processes as they occurred in the past, occur now and will probably recur in the future if institutions and processes are unaware of these problems or do not develop appropriate strategies to avoid them. It also aims to improve the skills of risk managers in judging which deficits are likely to be relevant to particular circumstances and in recognising which deficits can be eliminated or mitigated. The audience for the report includes policymakers, regulators, industry, scientists and non-governmental organisations (NGOs): in short, all those involved in assessing and managing risk.

The potential consequences of risk governance deficits can include, for example, lost opportunities and unrealised benefits, diminution of technological innovation and diffusion, and the loss of public trust. Many consequences of deficits may not be clear or quantifable at the time of their occurrence, but they can nonetheless be severe. One result of the BSE crisis is that it has taken years for the UK government to rebuild public confidence in the UK and around the world in the British food supply. Another example is asbestos, which was recognised as harmful to health as early as 1898, but the regulation of which is still incomplete (or non-existent) in some countries. It is estimated that in the European Union (EU) alone, the total disease burden of asbestos could be between 250,000 and 400,000 deaths over the next 30 years [Gee and Greenberg, 2002].

There are many existing and emerging risks of natural or human origin, including natural catastrophes, pandemics/epidemics, risks arising from lack of clean water, climate change, pollution, biodiversity loss, poverty, drug abuse, obesity, violence, geo-political risks, technology-based risks, infrastructure risks or financial risks. Together they harm millions of people every year, but some are more widespread and serious than others. It would be unrealistic to believe that all risks can be anticipated or managed, but many gaps in their governance could be remedied.

When risks derive (at least in part) from the interconnectedness of the modern world, challenging key functions of society, we refer to them as systemic risks. The term systemic risk is more familiarly used to describe financial risks which affect an entire market rather than a few individual participants. In line with the definition given by the Organisation for Economic Cooperation and Development (OECD) [OECD, 2003], IRGC has defined systemic risks as: “Those risks that affect the systems on which society depends – health, transport, energy, telecommunications, etc. Systemic risks are at the crossroads between natural events; economic, social and technological developments; and policy-driven actions, both at the domestic and international level” [IRGC, 2005]. The rapid spread of Severe Acute Respiratory Syndrome (SARS) to many countries, and its impact on trade, tourism and the economy as well as on public health, is one example of a systemic risk; others include the cascading failures of interconnected electricity grids and how climate change will affect, in various ways, almost all of the world’s populations and ecosystems. Systemic risks typically have impacts beyond their geographic and sector origins and may affect the systems – for instance, financial or ecological – on which the welfare of the planet depends. IRGC focusses on systemic risks because they may be quite intractable and devastating yet require cooperation among countries – or even a formal process of global collective action – to be effectively addressed.

Risk governance deficits operate at various stages of the governance process, from the early warnings of possible risk to the formal stages of assessment,

management and communication. Both *under-estimation* and *over-estimation* can be observed in risk assessment, which may lead to *under-reaction* or *over-reaction* in risk management. Even when risks are assessed in an adequate manner, managers may under- or over-react and, in situations of high uncertainty, this may become clear only after the fact.

Human factors influence risk governance deficits through an individual's values (including appetite for risk), personal interests and beliefs, intellectual capabilities, the prevailing regulations or incentives, but also sometimes through irrational or ill-informed behaviour. The report illustrates the impact of human factors on risk governance, for example in the case of fraud (Enron), or the adoption by well-intentioned regulators of an over-zealous or apathetic approach to new risks.

For each risk governance deficit, this report first provides a brief generic description, giving short explanations of some of the conceptual challenges facing risk managers. The sequence of deficits does not imply an order of priority. Each deficit description is followed by one or more examples of how the deficit has occurred during the handling of past and current risk issues and what the consequences have been on the organisations involved. As will be seen, diagnoses of the causes of deficits and their resulting consequences are not always straightforward, even with the benefit of years of hindsight. Thus, we have focused on illustrations of deficits where some consensus exists or where it is feasible to describe a range of opinions about their causes and consequences.

In addition, case studies have been written to reflect as much of a consensus as possible, although there will always be a subjective element to such analyses. The case studies are:

- The regulation of genetically modified crops in Europe
- The response to Hurricane Katrina
- Electromagnetic fields and radiation
- Fisheries management and depletion
- The BSE epidemic in the UK

The full text of these case studies can be obtained from IRGC. Summaries, plus a brief overview of the subprime crisis in the United States (US), have been added in an annex to this report.

In considering the causes of the most frequently occurring risk governance deficits, this report is organised into two clusters related to (A) the *assessment and understanding of risks* (including early warning systems), and (B) the *management of risks* (including issues of conflict resolution). Deficiencies or failures in communication related to risk assessment and management, including how the dialogue with stakeholders is organised, are relevant to multiple deficits in both clusters. Therefore, in this report risk communication issues are integrated into many of the deficit descriptions rather than addressed separately. This integrative role of risk communication is also emphasised in the IRGC Risk Governance Framework in a way that distinguishes it from many conventional concepts in which risk communication is either a separate category or only a part of risk management.

- **Cluster A** describes 10 deficits that can arise when there is a deficiency of either scientific knowledge or knowledge about the values, interests and perceptions of individuals and organisations.
- **Cluster B** describes 13 deficits related to the role of organisations and people in managing risks, showing the need for adequate risk cultures, structures and processes.

This report can serve as guidance for policymakers and practitioners in the public, private and non-governmental sectors concerned with fair and efficient risk governance and interested in avoiding risk governance deficits and their impacts. The guidance is therefore intended to promote thinking about whether an organisation has the right procedures in place to deal with risks as they are recognised, even risks that are only vaguely known or the full ramifications of which are not yet understood.

II Cluster A: Assessing and understanding risks

Accurate knowledge and understanding are essential for effective risk governance. Knowledge is needed to reduce complexity and uncertainty and to understand ambiguity. It is needed to clarify the often confusing interactions between multiple sources of harm, what causes them to become risks, and their potential physical, social and economic consequences. Knowledge can also help to quantify the levels of risk to be experienced by different individuals and communities.

Understanding is equally important. If knowledge exists but is not understood by decision-makers, stakeholders and the public, risk governance becomes highly vulnerable to error and unpredictability.

Two types of knowledge are relevant here:

1. *Scientifc knowledge* about the physical properties of a risk, such as: hazards, exposure and vulnerabilities; the probability of the risk occurring; and, the potential impacts and consequences if it does; and
2. *Knowledge of risk perceptions* and their underlying determinants and consequences, such as: stakeholders' interests and values; recent coverage of risk in the mass media; and, the social, economic and political consequences of confict between experts', decision-makers' and lay-peoples' perceptions of risk.

Disagreement in risk governance may arise from "conficting values as well as conficting evidence, and, in particular, from the inadequate blending of the two" [IRGC, 2005]. Risk governance defcits thus emerge when the knowledge base is defcient or inadequate as the result of:

- A lack of scientifc evidence about the risk itself, or of the perceptions that individuals and organisations have of the risk;
- Application of inappropriate methods, models or scenarios to derive this evidence;
- Failure to understand or take account of available knowledge; and/or
- Misuse of available knowledge, intentionally or unintentionally.

It is important to acknowledge that there will never be suffcient capacity to assess all the information relevant to a systemic risk. Thus a crucial skill of the risk assessor, and responsible managers, is deciding what information can be ignored and what simplifcations can be made. For risks of a systemic nature, a holistic approach to risk assessment would be ideal, encompassing the full scope and scale of the risk, but this is not practicable. Conclusions need to be drawn from analyses with more limited scope. Furthermore, the key information may undermine particular interests, intentions or plans, or contradict deeply-held ideological or moral values [Tetlock and Oppenheimer, 2008]. Decision-makers may prioritise information based on expediency or other personal, economic or political considerations.

In dealing with these challenges, IRGC's approach to risk governance highlights the related knowledge requirements. IRGC applies the term *complex* to risks for which it is diffcult to identify and quantify causal interactions among many potential agents and thus to determine specifc outcomes. Complexity is often inherent in natural and man-made phenomena and is not just a defcit of understanding or measurement. The term *uncertainty* is used by IRGC to refer to a state of knowledge in which the likelihood of any adverse effect, or indeed the nature of the effects themselves, cannot be precisely described. *Ambiguity* occurs when there are several alternative interpretations of risk assessment information. For *simple* risks (e.g., the risk of fre in a residential home), a promising regulatory action may be straightforward (e.g., required installation of smoke detectors and sprinklers). However, for the *complex, uncertain* and/or *ambiguous* risks described here, risk assessment is considerably more demanding and the scope for defcits is correspondingly greater.

Complexity, uncertainty and ambiguity are prevalent in our interconnected and fast-changing world. Innovation and globalisation in information and communication

technologies have created more interdependencies between regions of the planet. No sector of society – economic, environmental, technological, religious or socio-political – is isolated from this interdependence. Complexity, uncertainty and ambiguity make precise risk assessment more challenging and demand both analytical and organisational innovation from participants in risk governance.

These problems apply in both the public and private sectors. While governments have the primary responsibility for the security and safety of their citizens, there are many risks where the private sector has to take responsibility (e.g., product safety). Furthermore, many systemic risks can be successfully assessed only by including a combination of perspectives from public and private actors. Some examples might be the security of the energy supply (with many countries now having privatised the supply and distribution of gas and electricity, while energy policy remains in the hands of the government) or assessing the potential impact of a pandemic disease outbreak (for which governments will assume responsibility through public health plans, while business will deal, for example, with aspects such as business continuity or the production of vaccines – see cluster B).

This cluster describes deficits in risk governance relating to the research, analysis, interpretation and communication of knowledge about systemic risks. Each deficit is accompanied by real-world illustrations of how the deficit has affected past or current risk governance activities.

A1 Early warning systems

Missing, ignoring or exaggerating early signals of risk

The basic problem is simple: how do we look for something that we do not yet know about or fully understand? Early warning systems as a foundation of risk governance may be formal (as in the radar systems used to detect Luftwaffe missions in World War II) or informal (as in the discovery by Turkish haematologists that shoemakers who used benzene as a solvent for adhesives contracted aplastic anaemia and other blood abnormalities). When early warning systems are perfect, they prevent serious harm without causing any false alarms.

A signal from the warning system may be weak or strong. It typically exists long before a risk comes to the attention of decision-makers or the public, especially in cases of very slow changes within a system. The warning system accumulates information until a determination is made (based on human judgement and/or a computer algorithm) as to whether something is significant enough to trigger further action (e.g., develop risk scenarios and risk mitigation strategies). The warning system may itself be considered a form of risk assessment, or the system may produce data that are subsequently used by risk assessors in more in-depth analyses.

False negatives (no indication of a risk when one is actually present) and false positives (erroneous signals indicating something is present when it is not) in early warning systems are unfortunate realities. When a system is too insensitive, it fails to detect an emerging risk (e.g., the signal-to-noise ratio may be too small, causing the system to miss the worrisome evidence). False negatives are harmful because they allow an emerging risk to unfold without in-depth risk assessment or preventive action being taken by decision-makers before any damage occurs. For example, if a new technology increases the risk of a common disease, clinicians may not recognise the early cases among their patients, and epidemiologists may have difficulty detecting the statistical elevation among the large number of cases of the disease.

False positives can also be a serious problem if decision-makers expend resources needlessly, leaving fewer resources available to address genuine risks. False positives – especially if they occur repeatedly – can also create a potential crisis of confidence (or mistrust) that can lead to future accurate warnings being discounted or ignored (“cry wolf” syndrome).

History teaches us that false alarms are costly in both human and economic terms. A series of false alarms helped create a climate of complacency at Pearl Harbour prior to the Japanese attack at the onset of World War II’s Pacific engagement. More recently, concerns have been raised that over-reliance on high-dose animal experiments may have produced false

positives in chemical regulation. For example, the artifcial sweetener saccharin was shown to cause bladder tumours when huge doses were administered to rodents in the laboratory and the United States Food and Drug Administration (FDA) sought to ban the sweetener. Further scientifc evidence from biology and large-scale epidemiology demonstrated that the high-dose rodent tests on saccharin were not relevant to human experience.

Advances in science and technology are both helpful and problematic. Creative innovations in warning systems may cause a reduction in the rates of both types of error. However, advances in warning systems may also permit the detection of minute perturbations that are not indicators of real risk. For example, new blood monitoring systems have detected a surprising number of man-made chemicals in the human body but it is not yet clear whether the presence of these chemicals in small quantities is an indicator of potential harm.

Human judgement in the design of early warning systems and the subjective interpretation of their results are unavoidable. Therefore, expert groups involved in making such judgements should ideally be composed of individuals with varied experience and educational and cultural backgrounds. Those involved with warning systems, whether engaged in horizon scanning for governments or risk management in business, need to be both rigorous and open-minded as to the interpretation of signals, which means being attentive to low-level or subtle signals without over-reacting to random noise in data.

The subprime crisis in the United States

- The risks of home foreclosures were spread to investors throughout the world without transparency about what those risks actually were, while the few experts expressing concern were ignored.

The subprime crisis that began in 2007 originated in the US, had major adverse impacts on the international fnancial system and rapidly grew into a global economic crisis. Some banks and other important fnancial institutions failed, others made large write-offs and write-downs, and commodity and stock markets fell sharply as investors lost confdence; the global credit market froze. In turn, many of the world's economies went into recession and millions of people lost their jobs.

It appears that numerous factors contributed to the housing bubble and fnancial meltdown: the loose monetary policy (as the US Federal Reserve Board exerted a downward infuence on interest rates) encouraged lending by banks; political pressure on lenders increased rates of home ownership among lower-income households, especially in Hispanic and African-American communities; the sale of "subprime mortgages" to people whose income, assets and credit history were insuffcient to meet standard ("prime") qualifcation thresholds; the creation and sale to investors of increasingly complex fnancial products (securities) linked to these subprime mortgages, products with risks that were not transparent in fnancial markets; a herd mentality of participants in the fnancial market; and a lack of adequate regulation of fnancial markets. The system-wide risks arising from these factors were not predicted by the standard risk models used by fnancial analysts on Wall Street and around the world.

Although few, if any, experts anticipated (or were even able to imagine) a crisis of this magnitude, there were, with the benefit of hindsight, some early warning signs that the risk models were too simplistic and that the market was deeply unsound. In fact, some concerns were voiced by prominent economists, fnancial experts and reporters long before the crisis occurred. For example, as early as 2000, the former Federal Reserve governor, Dr Edward M. Gramlich, warned the then chairman of the Federal Reserve Board, Dr Alan Greenspan, about what Gramlich considered to be "abusive" behaviour in the subprime mortgage markets [Soros, 2008]. Several years later, in August 2003, journalists with The Economist published a lengthy article warning of the "unpredictable and possibly painful consequences" of credit-risk transfer (a driving force for the sale of derivatives based on subprime mortgages)

and improper regulation of the credit securitisation market [Economist, 2003]. These early warnings, based on professional judgement, were swept aside as incorrect or alarmist assumptions concerning market dynamics. In effect, the supreme confidence that housing prices would continue to rise, coupled with the drive for short-term profit and a fragmented regulatory system, prevented controlling authorities from taking any serious action to avert the crisis.

Tsunami early warning system in South-East Asia

- Lessons learned from a past failure led to the development of a promising new early warning system.

The tsunami that hit South-East Asia on December 26, 2004 killed more than 140,000 people in Banda Aceh, Indonesia, and approximately 230,000 people in total. Despite Indonesia's vulnerability to earthquakes and tidal waves (because of its position on the Sunda Arc, a subduction zone where three tectonic plates meet), there was no tsunami early warning system in place, nor was there adequate communications infrastructure to issue timely warnings. A tsunami warning system for the Pacific Ocean had existed since 1965. The effectiveness of such systems has been proven [IOC, 2008] and the lack of one for the Indian Ocean was a major contributing factor to the many deaths in this case.

Following the 2004 disaster, a framework for an Indian Ocean tsunami warning system was launched under the auspices of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) and its Intergovernmental Oceanographic Commission in 2005 [UNESCO, 2005]. Indonesia has since been developing and installing a tsunami warning system in partnership with Germany – the German-Indonesian Tsunami Early Warning System [GITEWS, 2008] – that uses new scientific procedures and technologies to optimise the system for Indonesia's unique geological situation. Even though it was only partially operational (the system was officially launched on November 11, 2008), it successfully detected an earthquake of 8.4 magnitude off Sumatra on September 17, 2007, allowing Indonesian authorities to issue a tsunami warning 15-20 minutes before the wave hit [Helmholtz Association of German Research Centres, 2008; Normile, 2007].

A2 Factual knowledge about risks

The lack of adequate knowledge about a hazard, including the probabilities of various events and the associated economic, human health, environmental and societal consequences

This deficit arises when there is inadequate knowledge about a hazard, about the probabilities of adverse events, about the extent to which people or other targets are exposed or about the extent of damages that may result. The lack of knowledge may occur because of insufficient or misdirected scientific efforts, or the requisite knowledge may be very difficult to obtain. This period of inadequate knowledge may be temporary or it may persist for a long time. If adequate knowledge exists but is ignored or resisted, this can lead to important deficits in management (see cluster B).

Lack of knowledge about a risk – its physical or other properties – is most likely to occur when risks are in their emergent phase, a period when fundamental risk drivers or cause-effect relationships are not yet established and scientific understanding is limited or spotty. Often, rather than being totally absent, relevant data are of poor quality or incomplete, particularly when complex processes of change are underway (e.g., climate change), when new technologies are introduced (e.g., xenotransplantation) [OECD, 2003] or when sudden disruptions take place (e.g., the

2007 collapse of housing prices in the US, UK and elsewhere, and the associated global financial crisis).

Sometimes inadequate knowledge can be traced to insufficient funding of scientific research (this was a serious problem at the early stages of the acquired immune deficiency syndrome, AIDS, epidemic). But inadequate knowledge can also result when well-funded scientists cling to outmoded theories, apply the wrong or one-sided methods when investigating a new risk or fail to investigate a subpopulation (of people, communities or wildlife) which is particularly vulnerable to an emerging risk. Additionally, scientists or decision-makers may simply fail to ask the important questions, or they may even ask the wrong questions.

Scientific evidence will be seen as more robust if it is confirmed by results from more than one source. Evidence based on anecdotal reports, though sometimes perfectly valid, is treated with greater scepticism than evidence from well-designed, large-scale statistical studies. Early clinical reports suggested that silicone breast implants were related to auto-immune disorders but these reports were not confirmed by large-scale epidemiological studies.

Once relevant scientific data have been collected, deficits can also occur in the process of analysis and interpretation. When analysis and interpretation occur without rigorous peer review by qualified experts, errors are more likely to occur. Based on this experience, scientists give more weight to data that have been published in the open, peer-reviewed literature. This can prove to be a challenge for the private sector, as early publication can undermine sources of competitive advantage.

Difficult tasks for risk assessors are appreciating the degree of uncertainty associated with available knowledge (including any biases in how data are generated) and evaluating the impact of this uncertainty on the precision and robustness of the findings of a risk assessment. Inadequate knowledge will be used by some to argue that a risk has not been proven. Others will argue that the uncertainty means that an acceptable degree of safety has not been established. Given the imperfections of scientific and societal knowledge and understanding, risk governance strategies and policy choices will often be made in the absence of reliable evidence.

Much of the available knowledge about hazards, including the probabilities and loss estimates in risk assessments, can be fully understood only by experts. Yet scientists and risk assessors may fail to communicate their knowledge to the decision-making bodies, let alone the general public. At the same time, public debates about risk may be complicated by the introduction of pseudoscientific claims, sometimes called “junk” science. The confusion resulting from pseudoscience may lead to exaggeration of risk (e.g., early false alarms that drinking coffee causes bladder cancer) or false assurances of safety (e.g., early claims that breathing environmental tobacco smoke is harmless).

Radio-frequency electromagnetic fields

- The tendency to confuse the lack of evidence of risk with a demonstration that no risk exists.

Radio-frequency electromagnetic fields (EMFs) have been present since the early 20th century and human exposure to them has grown rapidly in recent years. Produced primarily by radio, television, mobile phones, radar and microwaves, radio-frequency EMFs have frequencies between 10MHz and 300GHz [WHO, 1999] and, if the radiation is of sufficient intensity, can cause biological tissue to heat up [SAEFL, 2005]. However, in daily life, we are not exposed to radio-frequency EMFs of sufficient intensity to cause thermal effects that are harmful to human health [SAEFL, 2005].

Nevertheless, questions remain as to the health hazards of possible *non-thermal* effects of radio-frequency EMFs. Despite numerous studies, scientific knowledge remains unclear or equivocal [NRPB, 2003]. The collection of studies

to date shows some weak positive results (presence of detrimental effects), but results are often inconsistent between studies and cannot be replicated [WHO, 1999; SAEFL, 2005]. The World Health Organization (WHO) has thus concluded that "current evidence does not confrm the existence of any health consequences from exposure to low level EMF" [WHO, 1999]. Absence of evidence is not necessarily the same as evidence of absence, and often does not suffce to allay public fears. For example, "although studies do not suggest a raised risk of cancer, they do not rule one out, especially in relation to large cumulative exposures to mobile phones and possible effects occurring many years after their use" [NRPB, 2003]. More research, including studies with a longer latency period, will be necessary to improve scientifc knowledge in this feld, but will be challenging to carry out because of rapid changes in technology [Kheifets et al., 2008].

Replacing one gasoline additive with another

- Failure to fully utilise existing knowledge in risk assessment and to undertake further scientific investigation into a chemical additive's risks.

Methyl tertiary-butyl ether (MTBE) has been used as a gasoline additive in the US since the late 1970s, when it began to replace tetra-ethyl lead as an octane enhancer. Since 1992, MTBE has been used in higher concentrations by refners in order to meet the requirements of the US Clean Air Act Amendments, as MTBE reduces the level of harmful carbon monoxide and some other pollutants when gasoline is combusted. While alternative octane enhancers exist (e.g., ethanol), MTBE was preferred because of its favourable blending properties in pipelines and its low production cost [US EPA, 2008].

It was also well-known that MTBE had some negative properties. Laboratory studies suggested that, because of its limited biodegradability, MTBE was highly mobile and persistent in surface and groundwater [Barker et al., 1990]. Some comfort was taken from the fact that MTBE has a distinctive odour and taste that is detectable at very low concentrations in water. In other words, people would object to drinking it before they became sick from it. Nevertheless, no risk assessment was performed on a key question: "What will happen if the MTBE leaks from underground storage tanks into groundwater at numerous locations around the country?" In fact, without adequate assessment, some environmental groups and regulators joined MTBE producers in avid support of MTBE as a gasoline additive in their pursuit of improved air quality.

In the mid-1990s, it was discovered that MTBE had leaked from underground petroleum storage systems and pipelines into numerous bodies of surface and groundwater. Drinking water supplies were contaminated in several communities, including Santa Monica, California. Questions about the safety of MTBE led to hundreds of lawsuits being brought by water suppliers and users against oil companies and MTBE producers [Wilson, 2008]. The groundwater contamination problem has since become widespread (24 US states report fnding MTBE at least 60% of the time when sampling groundwater). Large amounts of drinking water became unusable because of the odour and taste of MTBE.

The adverse human health effects of MTBE exposure were never established with certainty [GAO, 2002]. Much of the standard toxicology of MTBE is reassuring (i.e., MTBE is not acutely toxic) but the long-term safety of continuous MTBE exposure is not well understood, and a risk of cancer is possible [Toccalino, 2005; Krayer von Krauss and Harremoes, 2002].

A3 Perceptions of risk, including their determinants and consequences

The lack of adequate knowledge about values, beliefs and interests, and therefore about how risks are perceived by stakeholders

Defcit A2 (above) is related to knowledge about probabilities and consequences of adverse events, whereas this defcit focusses on knowing and understanding how risks are perceived by non-scientifc publics, including ordinary citizens, business managers, representatives of stakeholder groups and politicians. Since a variety of values, interests, and cultural, familial, economic and ideological factors help *shape* perceptions, social scientists contend that perceptions of risk are "socially constructed" [Bradbury, 1989]. Effective risk governance requires consideration of both the factual aspects of risk assessment (A2) and the socially constructed (A3) aspects of perceived risk.

Individual risk perceptions may be based on a person's economic situation, personality, education, experience, religion, group allegiances, and social and cultural environment. Organised groups may form based on risk perceptions (e.g., anti-nuclear advocacy groups), or members of pre-established groups (e.g., gun owners) may tend to possess similar perceptions of a wide range of risks.

Risk perceptions are not always constant. They can change as a result of information, experiences, dramatic portrayals in the press or entertainment media, and incentives, although changes are less likely to take place if the original perception is based on deeply-felt individual values or group ideology [Tait, 2001]. When perceptions are diffuse or tentative, they may be susceptible to substantial infuence. Once perceptions have hardened, they can be quite diffcult to modify, even with compelling evidence – for example, when perceptions of certain societal groups are so strong that they eventually lead to widespread stigmatisation of a new technology, as has been the case in many countries with nuclear power and in Europe with genetically modifed (GM) food.

Differences in perceptions are often studied at the level of individuals but variations also occur between communities, countries and regions of the globe [OECD, 2003]. Terrorism is more salient in the Middle East than in Australia. The same risk will be assessed as safer or more dangerous in some communities or countries than in others ll ŕ á " "

Some people are fascinated by casinos; others avoid them.

Perceived risks can be very different from the estimates derived from evidence-based scientifc assessment. For example, chemical additives to food (e.g., preservatives) are often perceived by consumers and activist groups to be more risky than is indicated by scientifc assessments, while pathogens in food are often judged by the public as less risky than scientifc assessments suggest. A risk assessment defcit can result from the inadequate handling of a situation where the predominant public perceptions diverge from, or even contradict, assessments based on scientifc evidence.

A concern assessment by social scientists as suggested in the IRGC framework [IRGC, 2005] can be of great assistance to policymakers by helping them to understand social claims and positions and to place concerns in a larger cultural context. However, measuring how risks are perceived can be quite complicated. When risk perceptions are studied, the work should be conducted by qualifed social scientists who are knowledgeable about research methods and validation procedures, and have suffcient resources to undertake informative surveys. Erroneous information about risk perceptions can mislead decision-makers as much as erroneous factual information about risks. In fact, inappropriate understanding of risk perceptions may exacerbate social mobilisation and this may itself infuence the acceptability of the risk (A5).sKsctsb5olrnbseysleHsmayybvbtisva usrbvxb

Risk perceptions of nuclear power

- Where experts may judge risks differently from lay-people.

In the case of nuclear power, public perceptions of risk have become central to the making of energy policy. Some countries have responded with moratoria and phase-outs, while others are encouraging – or even subsidising – the construction of large new nuclear plants. Where risk perceptions are salient, they may relate to nuclear accidents, nuclear waste transport or storage, nuclear terrorism or even nuclear weapons proliferation.

Expert judgements about the risks of nuclear power frequently do not correlate with public perceptions of risk. In one study, few experts judged the risks of domestic nuclear power to be larger than "very small", while 65% of the public did so [Sjöberg, 1999]. This probably results from the fact that, when considering a specific risk, experts tend to use the product of probability and consequences, whereas most people make general risk judgements using a multi-attribute perspective that includes catastrophic potential [Slovic et al., 1980]. Issues about mistrust of experts (especially those associated with the nuclear industry or the government) may also be a factor [Sjöberg, 1999].

Heightened public fears regarding nuclear power may be the result of different judgements of benefits and threats. However, they may also be due to biased media coverage [Brewer, 2006] and creative activism by resourceful anti-nuclear groups or a rigid anti-nuclear culture, as exists in Austria or Portugal [FORATOM, 2008].

As concerns about climate change and possible electricity shortages have grown, some people's perceptions have begun to change. Recent years have not witnessed an accident on the scale of Chernobyl or even the fully-contained Three Mile Island. Publicity affects risk perception and reduced publicity may be a factor in changing public perception. For example, the Swedish government recently (2008) announced that it would seek a reversal of its previous (1980) decision to phase out nuclear power. Swedish officials are now considering the construction of new nuclear plants [Kanter, 2009]. This reflects changing public attitudes in Sweden towards nuclear power, which have become more positive over the last ten years [Hedberg and Holmberg, 2009]. If acceptable ways of managing nuclear waste are found and implemented satisfactorily, public acceptance of nuclear power may continue to grow in many countries.

A4 Stakeholder involvement

Failure to adequately identify and involve relevant stakeholders in risk assessment in order to improve information input and confer legitimacy on the process

Risk assessment can be compromised when important stakeholders are excluded from the process. Stakeholders may have biases but they often bring indispensable or useful data and experience to the risk assessment process. Excluding relevant stakeholders also reduces trust in the resulting analytic determinations and the legitimacy of subsequent policy decisions. There are multiple methods for involving stakeholders (e.g., an opportunity to make a technical presentation before risk assessors or the opportunity to serve as a scientific peer reviewer) that can be considered on a case-by-case basis.

The early stages of a risk assessment process may be a particularly fruitful time to seek suggestions from stakeholders and involve them in a risk dialogue. At this time, decisions need to be made as to the precise nature and understanding of the risk itself (how it is "framed"), the scope and depth of a risk assessment, the types of data that will be collected, the types of experts and contractors that will be commissioned, and the schedule for preparing and reviewing the risk assessment report. Stakeholders may have useful input on all of these questions.

Just as important as the task of gathering knowledge is the process of engagement that can lead to better risk communication. Creating an interactive process for exchanges of information or opinion between stakeholders, so that they are aware of what is occurring at each step of the risk assessment process, can lead to improved understanding of the risk issues by all affected. It can also help to build up trust in the openness and fairness of the risk assessment process and this, in turn, helps to improve its effectiveness.

Identifying and selecting which stakeholders should participate in risk assessment is important and not always straightforward. It may be a mistake to invite only those with extreme views about risk but it may also be a mistake to include only those with centrist interpretations of the science. While it is important to be open to suggestions from stakeholders, public authorities as well as private sector players should be careful not to provide an opportunity for particular stakeholders to impose their interests and biases on the risk assessment itself. Perhaps the most relevant criteria for the inclusion of stakeholders are: the ability to contribute useful knowledge or experience (including, for example, industry experts and relevant day-to-day experiences of vulnerable populations to risks such as flooding); the capacity to participate in a constructive manner; and, the potential to confer some legitimacy to the risk assessment process. Here the input from stakeholders should focus on science-related issues (including perception-related issues if a study of risk perception is being undertaken). Stakeholders who are not able or willing to participate in the technical aspects of risk assessment may still be appropriate for inclusion in the later phases of risk management (see cluster B).

It is not always feasible or advisable to involve stakeholders. Time and resource limitations will affect whether stakeholders are consulted, how they are consulted and whether public opportunities for risk dialogue between stakeholders and risk assessors are provided. An excessive emphasis on inclusiveness can slow down the process of risk assessment, leading to efficiency losses and diminished trust in the process; it can also have the effect of concealing responsibility or shifting it away from the managers and elected and appointed officials accountable for risk decisions. In most cases, however, an opportunity for some form of stakeholder involvement is likely to be helpful.

Large infrastructure projects (dams)

- Stakeholder involvement in the risk assessment process can improve public acceptance.

The World Commission on Dams reported that “the need for improvement in public involvement and dispute resolution for large dams may be one of the few things on which everyone involved in the building of large dams agrees” [WCD, 2000]. It has accordingly declared as a strategic priority the need to improve the “often secretive and corrupt processes which lead to decisions to build large dams” [McCully, 2003]. Critics of large dams have long called for water and energy planning to be made more participatory, accountable and comprehensive. The World Bank has echoed these concerns in a recent sourcebook [ESMAP/BNWPP, 2003].

For example, the building of the Nagara River Estuary Barrage in Japan was planned in 1968 for food control and protection of the water supply. Numerous conflicts and lawsuits delayed its construction and members of the public drew attention to the need to include issues such as sustainability and nature conservation in the risk assessment. However, because the Ministry of Construction and the Water Resources Development Agency had begun to deal with the project within a traditional frame, using a top-down public-sector approach, they were initially unwilling to listen to these representations and dismissed public concerns about lack of participation.

Ultimately, the knowledge contributed by the local representatives was brought into the assessment process and a

system for publicly monitoring the impact of the Barrage on the river ecosystem was proposed. This change in the risk assessment process, including constructive dialogue with stakeholders, allowed planning for construction of the Barrage to proceed beyond the risk assessment phase. If the relevant stakeholders had been brought into the assessment process earlier, the conflict might have been less protracted [Okada et al., 2008].

A5 Evaluating the acceptability of the risk

Failure to consider variables that influence risk acceptance and risk appetite

Once a risk has been assessed from a scientific perspective and the analysis of concerns and perspectives has been completed, decision-makers must determine whether the risk is acceptable[1] and thus whether it requires specific risk management. Although acceptability is a value-laden judgement that people may sometimes seek to avoid, it is a necessary one in a sound risk governance framework. Essentially, thresholds for risk acceptability depend on how risks and benefits are balanced. The valuation of potential benefits (whether this value is related to monetary gain, improved welfare, or moral or ethical considerations) is key to whether one is willing to accept the associated risk.

Even if the scientific aspects of risk assessment are sound, there may be a failure by decision-makers to consider variables that influence the acceptability of risk or consumer confidence in a product. Terminology is not uniform, but an inquiry into risk acceptability is called “risk evaluation” in the IRGC Risk Governance Framework.

In addition to the valuation of potential benefits, social scientists have determined that a variety of other variables appears to influence public acceptability of risk, beyond the probability and severity determinations that dominate the scientific assessment of risk. These factors include: whether the risk is incurred voluntarily or is imposed on citizens without their informed consent; whether the risk is controllable by personal action or whether it can be managed only through collective action; whether the risk is incurred disproportionately by the poor, children, or other vulnerable subpopulations; whether the risk is unfamiliar and dreadful; whether the risk results from man-made rather than natural causes; and, whether the risk raises questions of intergenerational equity [Bennett and Calman, 1999].

Although a risk may appear to be acceptable (or even negligible) based on purely probabilistic considerations, segments of the public may consider it unacceptable for a variety of psychological or ethical reasons, as has happened with GMOs in Europe and some applications of nanotechnology in several countries.

To some extent, the inquiry into risk acceptability draws on the risk perception issues discussed earlier (see A3). In some public settings, however, the inquiry is more specific and entails a formal determination of risk acceptability under an explicit statutory or administrative standard. The factors involved in a formal risk-acceptability decision may vary depending upon the legal context. Under US law, for example, a distinction is often made between an “imminent hazard” (a high degree of unacceptability that triggers emergency measures) and a “significant risk” (also unacceptable, but potentially manageable through normal rulemaking procedures). Terms such as “unreasonable risk” and “negligible risk” also have specific meanings under various US laws and regulations. Such legal standards of acceptability may have less prominence in countries that do not share the US emphasis on litigation-oriented solutions to risk issues.

Deficits in risk acceptability often occur when organisations and stakeholders fail to define the type and amount of risk that they are prepared to pursue, retain or take (*risk appetite*) or to take relevant decisions based upon their attitude towards turning away from risk (*risk aversion*). This implies that, in order to make good risk management decisions (cluster B), organisations and stakeholders need to define their level of *tolerance* for each risk they

1) In other publications IRGC distinguishes between acceptable risk (needing no specific mitigation or management measures) and tolerable risk (where the benefits exceed the potential downside but require management strategies to minimise their negative impact). Here we group both as acceptable risk.

face (the organisation or stakeholder's readiness to bear the risk after risk treatment in order to achieve its objectives) [ISO, 2009]. In the private sector in particular, risk decisions will have to explicitly state the level of loss that the organisation is prepared to accept in its operations.

Radioactive waste disposal

- Fairness aspects in determining risk acceptability.

Radioactive waste disposal facilities can pose health and environmental risks for local residents, both present and future. Equity considerations, intra-generational and inter-generational, are thus often pre-eminent when assessing risks related to the siting of such hazardous facilities [OECD NEA, 1995]. A common concern is that present and future residents near proposed sites should not be expected to accept a greater burden of risk than other sections of society (who are equally implicated in creating the waste problem). Two of the most emphasised fairness criteria are "technical efficiency" (the site with minimal overall risk should be chosen) and "contribution to the problem" (those who generate the waste should bear the risk) [Vari, 1996].

In the US in the 1970s, fairness issues regarding three low-level radioactive waste (LLRW) disposal facilities were brought before Congress when the states of South Carolina, Nevada and Washington indicated that they were no longer willing to receive and store waste from the rest of the country and thus bear a disproportionate amount of risk. In response, Congress enacted the Federal Low-Level Radioactive Waste Policy Act of 1980, making each state responsible for the disposal of LLRW produced within its borders [Vari, 1996]. When underestimation of the degree of citizen opposition caused state cooperation and regional solutions to fail, more states were forced to build LLRW disposal sites. Not only was this inefficient, but it *increased* the number of people put at risk by such facilities. In this case, acceptability of risk depends on difficult trade-offs to be made between efficiency and equity issues. Equity issues can be some of the most complex and intractable for policymakers, and must therefore be handled with care. As this case demonstrates, "inequality does not necessarily imply inequity. If the risk burden is unequally distributed, spreading risks more widely does not actually make it more equitable" [Coates et al., 1994].

A6 Misrepresenting information about risk

The provision of biased, selective or incomplete information

This risk governance deficit refers to cases where efforts are made to manipulate risk governance through the provision of biased, selective or incomplete knowledge (or a failure to ascertain the objectivity, quality and certainty of submitted information). Often, this misleading information is submitted by stakeholders who seek to advance their interests, but it may also be submitted by government officials seeking to protect themselves from criticism or by enterprising journalists or reporters who seek to create an interesting story. The deficit is therefore related to a lack of open, unbiased communication.

In dealing with knowledge-related deficits (see A2 and A3), each attribute of the risk science – complexity, uncertainty and ambiguity – can be either over- or understated by participants in the risk assessment process. Strategic manipulation of information is a classic interest-group strategy but it is particularly difficult to challenge misleading submissions about risks when knowledge is uncertain and clear evidence is lacking to support a particular position or decision; a fact-based rebuttal is therefore impossible. When analysts and policymakers are misled by erroneous or biased information, many types of error in risk management (e.g., over-regulation, under-regulation or misdirected regulation) can occur. Accurately conveying uncertainty about a risk (for example, the severity and stage of a pandemic) can be challenging, and erroneous information should in this case not be understood as a deliberate attempt to manipulate data. Misrepresentation may also, therefore, be

unintentional. Recipients of the information should be made aware of this.

Although some prefer a risk assessment process that is grounded in the respectful behaviour typical of a scientifc process, real-world risk assessment processes sometimes resemble a harsh political debate, and controversy is not necessarily a

methods, Shell decided that the best practicable environmental option was deep-sea disposal in UK territorial waters. Permission for this option was granted by the UK Department of Trade and Industry in December 1994 [Löfstedt and Renn, 1997].

In early 1995, Greenpeace began a campaign to block the implementation of Brent Spar's deep-sea disposal, as they claimed the buoy contained large amounts of oil and hazardous materials (in line with its campaign since the early 1980s against dumping in the North Sea). An occupation of Brent Spar by Greenpeace activists and journalists in April 1995 received significant media coverage, predominantly supportive of Greenpeace, which catalysed effective consumer boycotts of Shell in Germany, the Netherlands and parts of Scandinavia in May 1995 [Löfstedt and Renn, 1997].

On June 16, 1995, Greenpeace carried out a second occupation of Brent Spar just as it was being readied for transport. Following this occupation, Greenpeace claimed that its scientific analyses of Brent Spar's storage tanks showed that they contained some 5,000 tonnes of oil, plus heavy metals and toxic chemicals, which Shell had failed to declare in its analyses. Shell publicly refuted these claims, stating that the remaining oil had been flushed out into a tanker in 1991, and that its full analyses of tank contents had been made public and had been widely reported [Shell UK, 1995]. Nevertheless, a few days later, Shell announced that it was calling off the deep-sea storage option and began a public relations campaign to try to salvage its reputation.

In July 1995, Shell hired a Norwegian company to conduct an independent audit of the allegations made by Greenpeace regarding the amount of oil and toxic substances in Brent Spar. Just before the report (which supported the figures provided in

associated with the knowledge held at the time. No scientifc evidence yet existed regarding BSE's transmissibility to humans from contaminated meat.

The government backed up its assertions that British beef was safe to eat by claiming that the precautionary regulatory controls it had implemented would prevent any contaminated material from entering the food chain, although the measures were not designed to eliminate exposure, only to diminish the risk [van Zwanenberg and Millstone, 2002].

Assertions regarding the safety of British beef turned out to be incorrect and, as a result, public health was endangered and 165 people to date have died in Britain from the human form of BSE.

A7 Understanding complex systems

A lack of appreciation or understanding of the potentially multiple dimensions of a risk and of how interconnected risk systems can entail complex and sometimes unforeseeable interactions

Interactions among the components of a complex system [OECD, 2003] raise numerous diffculties for risk assessment. For example, biological systems such as those involving infuenza in human, pig or bird hosts, or environmental systems such as large ecosystems, can be very complex, and this can lead to sometimes unforeseeable interactions and potential defcits. Such interactions include those involving a system's buffering capacity, which can serve either to amplify (through positive feedback loops) or attenuate (through negative feedback loops) the impact of a given event or set of events on the behaviour of the system. In practice, there is ample evidence for both risk attenuation and risk amplifcation [Kasperson et al., 1988]. Additionally, the impact of events occurring simultaneously can be very different from that of the same events occurring sequentially. Many of the concepts and methods applied in risk assessment of simpler situations will not be adequate if applied to complex systems [Lagadec, 2008].

It becomes diffcult to identify, understand and quantify the "causal links between a multitude of potential causal agents and specifc observed effects" [IRGC, 2005]. It is diffcult to assess the probability and the consequences of a risk being realised, especially the rapid spread of damages across geographical, functional or sectoral boundaries.

Where systemic interactions are possible or likely, assessing risk problems without acknowledging this complexity will not be fully informative [Sunstein, 2005]. For example, some risk assessments fail to take indirect effects or externalities into account[2] and thus trade-offs in decision-making about complex systems are overlooked[3]. As a result, efforts to reduce risks may create new (secondary) risks, unexpected consequences may occur in areas or sectors other than those targeted, and they may be more serious than the original risk. Finally, risks already believed to have been eliminated "can reappear in another place or in a different form" [Bailes, 2007].

Equally, the systemic nature of many risks means that there are ramifcations for the assessment of a risk's scope (domains of impact) and scale (extent of consequences). SARS was initially a new zoonotic disease confned to China but spread rapidly to many other countries and had, for example, a signifcant economic impact on the city of Toronto as well as on all airline companies with routes in the Pacifc region.

Assessing the impact of systemic interactions is one of the most important but least understood aspects of modern risk assessment. The way to address this is not simply through a cultural change in the risk community but through a sustained research programme to build better, validated tools that are applicable in these situations and to educate risk specialists to prepare for and cope with such situations.

2) For example, the indirect consequences of BSE have been judged "considerably larger than its direct consequences" [OECD, 2003].
3) On the pervasiveness of risk trade-offs, see [Graham et al., 1995].

The subprime crisis in the United States

- Failure to adequately comprehend the complex dynamics of financial systems contributed to the severity of the US subprime crisis.

The instigating event that led to the subprime financial crisis was the issuance of loans (subprime mortgages) to people who could not afford them. This created a substantial amount of risk. However, an important secondary problem that contributed to the severity of the crisis was the way in which these loans were re-packaged into complex financial products and then sold to investors (securitisation). A lack of understanding – by banks, investors, borrowers, lenders, policymakers and regulators – of the complexities of these financial products (and the markets in which they are traded) led them to miscalculate and underestimate risks.

(a) Failure to understand the consequences of decisions made in the subprime market:
While subprime mortgages had once been viewed as "a positive development" by many (including chairman of the Federal Reserve Board Dr Alan Greenspan) and as a move towards the democratisation of finance (e.g., a way to allow millions of low-income earners to purchase assets), they turned out to be something of a "disaster in their implementation" because "they lacked the kind of risk management institutions necessary to support the increasingly complex financial machinery needed to underwrite them" [Shiller, 2008]. This complex financial machinery included "a blizzard of increasingly complex securities" produced by Wall Street. These securities were then re-packaged to form other kinds of asset-backed securities or risk-swapping agreements so that, in the end, the final product was so complex that it was difficult or impossible for investors to assess the real risks of the securities they were buying. As a result, investors tended to put their trust in rating agencies that, it was assumed, had adequate data to properly assess securities' safety. However, rating agencies also had to deal with increasing complexity in the (often misleading) information provided to them by the originators of the mortgage loans and they were using new, untested models to evaluate novel loan schemes. This combination of factors led them to seriously miscalculate risks in many instances [Zandi, 2009].

(b) Failure to assess the properties and dynamics of financial systems:
At the regulatory level, there was also an important lack of understanding: of the nature of financial markets; of economic bubbles, their causes and aftermath; and, of the numerous feedback loops that could lead problems in the housing sector to cause global economic chaos. Some commentators believe that "policy-makers and regulators had an unappreciated sense of the flaws in the financial system" [Zandi, 2009]. For example, the US Federal Reserve Board's loose monetary policy between 2000 and 2004 seems to have increased the risk of financial instability in the context of the housing bubble that was growing at the same time. Such a policy (for 31 consecutive months, the base inflation-adjusted short-term interest rate was negative) probably would not have been implemented and maintained for so long had the federal regulators been able to fully understand the complex dynamics of the system, the nature of the housing bubble and the probability that it would burst, and the complicated web of investments (including from overseas) in the subprime housing market [Shiller, 2008].

Fisheries depletion: Barents Sea capelin

- Fishing, combined with the unexpected effects of changes in the environmental conditions, depleted the Barents Sea capelin stock and the entire fish ecosystem.

In the 1970s, the Barents Sea capelin stock maintained an annual fishery with catches up to three million tons

[Gjøsæter and Bogstad, 1998]. The stock then began to decline and in 1985 scientists recommended that no quota be set for 1986 [ICES, 1986]. The Joint Norwegian-Soviet Fisheries Commission found itself unable to follow this advice for political reasons, and a quota was set for 1986 [Hønneland, 2006] but the fshermen were not able to catch even this quota because there were so few fsh. The collapse was an inescapable fact and the fshery was closed until 1991, when it was partially reopened.

Although possible ecological mechanisms had been hypothesised before the collapse [Hamre, 1984; ICES, 1986], these were far from established. The collapse was later explained by a combination of environmental conditions. One was the unforeseen importance for capelin of the Norwegian spring-spawning herring stock, which has its nursery area in the Barents Sea. Since the herring stock had been depleted since the late 1960s, its role in the Barents Sea ecosystem had only been rarely studied. The increased infow of Atlantic water to the Barents Sea in 1983 provided favourable environmental conditions and resulted in an outstanding number of herring and cod larvae in the Barents Sea. What the scientists did not fully realise was the extent to which the young herring would graze on the young capelin, and that cod would eat a signifcant part of the maturing capelin stock. The combination of massive predation and fshing led to the depleted capelin stock [Tjelmeland and Bogstad, 1993]. The lack of capelin as prey fsh then led to poor growth and high mortality among the fsh, marine mammals and marine birds that depend on them, resulting in a more or less collapsed ecosystem [Hamre, 2003].

As a consequence, an extensive stomach-sampling scheme was conducted to map the complex interrelationships between the species in the Barents Sea [Gjøsæter et al., 2002]. Now that managers are warned when the observed abundance of herring larvae is high, the assessment of capelin takes into account the predation of cod and, overall, uncertainties are better addressed.

A8 Recognising fundamental or rapid changes in systems

Failure to re-assess in a timely manner fast and/or fundamental changes occurring in risk systems

Risk assessment is most straightforward when the analyst uses established tools in a relatively stable environment, where an accurate picture of the future can be predicted by extrapolating from past experience. When risks emerge unexpectedly because of rapid changes in the fundamentals of political, technological, environmental or economic systems, risk assessment becomes far more diffcult. In this case, risk managers may be forced to move away from using experience-based assessments (based on past data) and towards exposure-based assessments (based on anticipated data).

In such dynamic circumstances, individuals often continue to behave as if the risks follow known routines. They fail to recognise the fundamental changes that render simpler assumptions obsolete. Reactions to fundamental changes are often slow or non-existent because analysts and decision-makers do not expect or recognise them.

New risks can emerge rapidly (e.g., the early stages of the SARS epidemic) or they can be characterised by a creeping evolution where they are diffcult to identify at an early stage, spread only gradually and have consequences that cannot be recognised until a much later stage (e.g., the effects of global climate change or the negative health effects of asbestos fbres). In either case, the troublesome trends are detected too late.

Fundamental change may not become obvious until a previously unknown threshold or “tipping point” is reached and the system disruptively jumps to another

state. Such threshold levels are often identifed in the environmental domain (e.g., pollution of lakes and rivers, biodiversity loss, Gulf Stream turnaround), but economic systems can show similar behaviour as they are infuenced by psychological characteristics (e.g., herd mentality). Failures to react to such fundamental changes can lead to disaster.

The HIV/AIDS epidemic

- The uncontrolled and extensive spread of the virus was unanticipated and went unnoticed for a long time.

Since its frst diagnosis, in the US (Los Angeles) in 1981, AIDS – a new disease now thought to have zoonotic origins – has become a pandemic of disastrous proportions, with epidemics of differing severity occurring in all regions of the globe. At least 25 million deaths have already occurred. The very long latency period of the AIDS-causing human immunodefciency virus (HIV) infection before disease symptoms became obvious meant that, unlike most epidemics, it was able to become well-established before the causative agent could be identifed.

When AIDS was frst recognised as a distinct disease in the US, more than 100 cases were diagnosed within the frst six months, 3,000 within the frst two years and, by August 1989, 100,000 cases had been reported. While it took eight years to reach the frst 100,000, a second 100,000 cases were reported in only two years (November 1991), and the total fgure surpassed half a million in October 1995 [Osmond, 2003].

Researchers examining earlier medical literature have estimated that some persons in the US must have been infected with HIV as long ago as the 1960s, if not earlier [Osmond, 2003], indicating that the virus had been spreading for some time. However, accurate risk assessment was hampered by the long latency period, which meant that infection was "not accompanied by signs and symptoms salient enough to be noticed" [Mann, 1989], and in the early stages by scientifc disagreements over the nature of the causative agent. Once this was identifed, there was no effective treatment and there was disagreement over preventive measures that could halt the virus' spread.

Only when the frequency of infection reached a certain level and the spread of the disease became more extensive did the public in general realise the signifcance of the risks posed by HIV/AIDS. It was not until 1988 that the US government began a national effort to educate the public about HIV/AIDS. However, the gay community, as the most affected group, reacted with more speed and caution in assessing the risks they were facing. The raising of societal awareness, along with other HIV-prevention efforts, saw the number of new infections in the US decline rapidly after peaking in the mid-1980s [AMA, 2001]. Worldwide, HIV remains a huge challenge for public health offcials, despite a massive infusion of funds in Africa and elsewhere by the Bush administration.

Potato blight and the Irish Potato Famine

- A technological advance changed the dynamics of a system, creating new risks through allowing the spread of pathogens.

Late potato blight (Phytophthora infestans) is a virulent disease of potatoes which originated in the highlands of Mexico and is believed to have reached the US in the early 1840s. The disease thrives in cool, moist conditions and can also destroy tomatoes. The pathogen – an oomycete and not, strictly speaking, a fungus – survives on infected tubers [Karasevicz, 1995].

In the 1830s, a new form of sailing ship, the clipper, began to replace older, slower ships transporting goods from the Americas to Europe. This new vessel substantially reduced journey times but also allowed potato blight to reach Europe. The blight had previously not survived the journey even though it had caused the destruction of potatoes on board. Potato blight infection was noticed in the Isle of Wight (southern England) in 1844. In 1845, most of Ireland's potato crop was destroyed by blight and between 1845 and 1849 Ireland suffered, as a result of further potato harvests devastated by blight, a famine that was one of Europe's worst natural disasters. In all, Ireland's population fell by over 1.6 million between 1841 and 1851. One million people are believed to have died in Ireland, with starvation and typhus the main causes, and a further million emigrated, many on "coffn ships" to America on which as many as 20% died [Schama, 2002].

The development of the clipper constituted a fundamental change in international trading systems, substantially increasing the speed of passenger and goods movements and also increasing the risk of spreading diseases.

A9 The use of formal models

An over- or under-reliance on models and/or a failure to recognise that models are simplified approximations of reality and thus can be fallible

Risk assessors use formal (quantitative, semi-quantitative and qualitative) models both to understand the relations between components of a system and to estimate future trends under various assumptions. The use of models requires an understanding of their potential as well as of their associated assumptions and limitations. Models can provide useful approximations of "reality" and can help to bring clarity to complex risk assessments regarding potential future outcomes. For example, the use of epidemic models constitutes a valuable adjunct for decision-makers by allowing them to use available data to project the size and severity of a disease outbreak, while in the feld of climate change, models are probably essential tools. Consequently, decision-makers are making increasing use of large, complex computer-based models for exploring options in critical areas of economic, environmental and social risk.

Typically, models consist of a computational projection forward in time of certain key parameters (e.g., atmospheric temperature, economic growth, stocks of natural resources, statistics on population and ageing, or the number of new cases of HIV/AIDS infection) based on historical data and expert judgement of parameters. Given the intrinsic limitations of models and their possible deliberate or inadvertent misuse, policymaking and decision-making that is solely informed by or based on modelling results is a frequent source of controversy.

Without proper safeguards, quality control and transparency, there is a risk that the wrong risk mitigation measures or business and policy decisions could be implemented based on faulty models (i.e., over-reliance on imperfect models) or, conversely, that the necessary risk decisions will not be adopted owing to lack of confdence in the ability of scientists to make accurate projections with models (under-reliance on useful models). Striking the right balance in the use of models in decision-making is not easy. At the present time, formal modelling enjoys widespread support in the scientifc community and in both the private and public sectors, even though particular models or modelling predictions may be the source of intense criticism.

The growing recourse to models is linked to the fact that many risks (and other challenges facing modern societies) are impossible to comprehend using simple analytical or statistical methods. The challenges involve diverse elements that interact in complex ways on very large scales, thus precluding the use of common sense or historical precedent. Often, the societal challenges are directly linked to scientifc and technological phenomena: for example, energy production, the geosphere, climate change and biodiversity. These phenomena are to a large extent intrinsically quantifable and thus amenable to formal modelling. At the same time, the rapid growth

of information and communications technology (combined with the falling costs of memory and computational hardware) provide a strong incentive to create and apply computer models to guide decision-making about risk.

Despite the usefulness of models, there may be situations where too little is known about a system or set of scenarios to permit useful modelling. For example, catastrophic losses in situations of high uncertainty are unpredictable and immeasurable, and attempts to quantify them may not form a useful basis for action [Weitzman, 2008]. Yet it may not be obvious what the alternatives to imprecise computations are, and decision-makers will typically seek some form of guidance, especially in the case of potentially catastrophic losses.

In order to ensure that decision-oriented models are not dismissed or ignored in the future owing to highly-publicised cases of modelling faws or misuse, analysts and decision-makers should become aware of the limitations of modelling and the defcits that can result from their use and misuse. These limitations include:

- if assumptions regarding the phenomenon being studied are incorrect, the results may be of limited (or no) validity;

- the computer programme that embodies the model may itself be an extremely complex artefact and it may behave unpredictably, but in ways that are not self-evident to even an experienced user;

- because complex models usually contain large numbers of adjustable parameters, the outcomes of the computation can be adjusted (deliberately or inadvertently) so as to agree with desired values;

- those who build and run computer models do not always make them transparent – they may not document them properly and do not always make either software or data available for independent verifcation, especially by critics;

- the results that are presented to sponsors, colleagues or the public may represent only the selected “best” instances of running the model, with dubious or incomprehensible results being suppressed;

- results of computations that are presented for decision-making purposes often do not adequately specify the associated uncertainties (“error bars”) that result from imperfections in the modelling and in the input data; and

- when the results of modelling are made public, most journalists do not have the scientifc expertise to independently assess the results derived from complex models, so they tend to report as fact the most pessimistic or sensational projections and results, without accurately presenting uncertainties or alternative viewpoints or without giving adequate emphasis to the prediction that has the most scientifc support.

Given these limitations, it is hardly surprising that risk managers and policymakers (especially professional politicians) sometimes incorrectly extrapolate or even misinterpret the results of modelling exercises in order to support long-held personal strategic or ideological positions. Advocates from stakeholder groups (e.g., environmental activists or industry associations), including academic scientists aligned with these groups, may behave in similar ways. The defcit applies equally to business; the limitations of fnancial models were one reason for the subprime crisis and the wider economic problems it caused (see below).

Recognising some of these concerns, the US federal government has issued information quality guidelines that require all formal models used in regulatory policymaking to be transparent with regard to the data employed and the model structure (with a few exceptions) [OMB, 2002]. There is also a trend, stimulated by some professional and scientifc societies, to make greater use of websites to publicly disclose details about data and modelling structure that are not publishable in a scientifc journal (open source access). Despite these modest efforts, a case can be made that there is a need for more international deliberation and standards on the use of large-scale computer models in the risk handling process.

Fisheries depletion: Newfoundland cod

- Modelling used to estimate northern cod off Newfoundland proved erroneous.

Between the late 1960s and the late 1980s, industrial overfishing managed to wipe out the Grand Banks cod fishery, once considered one of the greatest in the world, to the point that biological extinction of the fish stock was considered a real possibility [McCay and Finlayson, 1995]. This occurred in spite of the government's employment of mathematical models to set total allowable catches (quotas). While models can be very useful and have an important place in fisheries management, this example demonstrates that models, and what they represent, are complex and that models can be fallible. How models are used is thus crucial to their usefulness and potential success.

Re-assessments of the abundance of northern cod indicate in hindsight that the abundance was overestimated by as much as 100% [Walters and Maguire, 1996]. There is broad agreement that the assessment model failed to represent nature and the impact of fishing in a way that was adequate for policymaking. However, several scientists have concluded that, given the data, the knowledge and the managers' dependence on a number from the fisheries scientists to set quotas, the collapse could not have been foreseen earlier [McGuire, 1997; Shelton and Lilly, 2000; Shelton, 2005]. In spite of the model's shortcomings and warning voices from parts of the inshore fleet and the scientific society [Finlayson, 1994; Rose, 2007], the mathematical model was a convenient tool for policymakers who wanted – more than anything – to avoid making the politically disastrous decision to halt or significantly decrease fishing [Pilkey and Jarvis-Pilkey, 2007]. Two years before the collapse, the scientists became confident that the stock had been severely overestimated. Yet, the managers chose to listen to the still-optimistic representatives from the offshore fleet and set a quota of twice the level recommended by the scientists [Rose, 2007].

Ultimately, the collapse became evident. There was a complete closure of the Grand Banks cod fishery in 1992 and, since then, the fishery has been reopened only sporadically and on an experimental basis. Cod stocks have still not recovered sufficiently to allow the fishery to reopen on a permanent basis [Hannesson, 2008]. The overfishing, with a fortified effect from environmental changes, may have changed the ecosystem structure [Frank et al., 2005] so that a recovery in the near future cannot be taken for granted.

an abstraction from the full detail of the real world" [cited in Shiller, 2008]. The variables affecting the fortunes of the subprime mortgage market were so many and so complex that developing accurate models, even for subsections of the securities markets, would have been very difficult, to say the least. Another difficulty facing modellers was that many financial products and loan schemes were new and had never been through a recession or a slump in housing values. This made developing accurate models very challenging (not least because modellers require historical data when building the models) and increased the risk that the models "were not up to the task they were asked to perform" [Zandi, 2009]. Too heavy a reliance on such shaky models led to serious miscalculations of risks and consequences by, for example, ratings agencies when providing opinions about the creditworthiness of securities [Zandi, 2009].

George Soros has contended that it was not only the simplicity of models or an over-reliance on them that proved dangerous. He has also criticised as false and in urgent need of replacement "the prevailing paradigm [that 'financial markets are self-correcting and tend towards equilibrium'] on which the various synthetic instruments and valuation models which have come to play such a dominant role in financial markets are based" [Soros, 2008]. Models are based on knowledge, causal chains and interactions. In the financial sector, however, participants cannot base their decisions on knowledge because in economics, as opposed to systems in the natural sciences, social phenomena exert a significant influence, with participants' views and psychologies coming into play and influencing behaviours. This indeterminacy introduces uncertainty into events and "outcomes are liable to diverge from expectations" [Soros, 2008].

A10 Assessing potential surprises

Failure to overcome cognitive barriers to imagining events outside of accepted paradigms ("black swans")

The history of influenza or past experiences of natural catastrophes teaches us to expect surprises. No one can reliably anticipate the future. This deficit, however, is not the failure to predict the unpredictable – which is, by definition, impossible – but the failure to break through embedded cognitive barriers to imagine events outside the boundaries of accepted paradigms.

Risk assessors and decision-makers may not realise that rare events can happen, presumably because they have never happened before, or not for many decades. For example, unexpected events of extreme impact (the so-called "black swans") [Taleb, 2007] or paradigm shifts that undo long-established truths must be acknowledged. Even if risk assessors are aware that such events and developments could occur, they may downplay them, ignore them or be helpless in considering how to take them into account [Lagadec, 2008].

One should not assume that rare surprises are always bad. But regardless of whether surprises are good or bad, better information and preparedness for a world with surprises make organisations more resilient.

One of the advantages of computer models is that they allow us to simulate the future based on alternative – even unlikely – scenarios. But more sophisticated tools to study and model risk issues will not necessarily resolve this deficit and expansion into more qualitative tools like scenario planning may also be needed. What is necessary as well is a focus on creativity and an openness to imagining the atypical, singular, exceptional or even inconceivable. This requires integrating lateral thinkers, including people from outside the established circles, in order to contemplate the unknown (and even the completely unimagined). More importantly perhaps, there is a need to counteract one of the many cognitive biases potentially affecting judgement on global risks: "not knowing what we do not know", and thus inviting potential surprises [Yudkowsky, 2008].

A key caveat is necessary here – each prediction from unconventional analysis should be, whenever possible, subjected to a "reality check" in which

surprising possibilities are re-examined in light of what is known and what is unknown about the behaviour of the system. Through this process of prediction and validation, the performance of unconventional thinkers can be compared to that of standard modellers, and directions for further analytical attention can be identifed. Obviously, the unconventional thinkers will also have error rates, potentially large ones.

The concept of unknowability used in financial risk assessment refers to "situations where the events defning the space cannot be identifed in advance", where there is no underlying model and risk assessors are unable to understand certain observed phenomena, conceive hypotheses and theories, or even identify the phenomena [Diebold et al., 2008]. It can be illustrated by black holes, which scientists could not look for until a theory was developed about how matter behaves under extreme gravitational forces. Unknowable risks are subject to defcits in their assessment until people understand that their existence is not predictable; that they cannot be characterised, measured, prevented or transferred; and that the only strategy for dealing with them will be to develop the capacity to deal with surprises (see cluster B). Thus, we turn to risk management, where failure to prepare for the aftermath of surprises (e.g., public health emergencies and terrorist events) is one example of a wide range of risk governance defcits.

9/11 terrorist attacks

- Nobody imagined the occurrence of events that were unthinkable within the accepted paradigm of terrorist behaviour.

When the terrorist attacks of 9/11 occurred, it seems that nobody had expected terrorists to use a civil aircraft as a bomb, as opposed to bringing a bomb onto an aircraft; nor had they imagined an airliner hijacking where no demands were made and no negotiation was possible. Even though a terrorist attack was not completely unexpected [9/11 Commission Report, 2004], most people regard the 9/11 attack as unexpected because the way in which it was carried out was unthinkable.

This could be blamed on intelligence failures – failure to detect early warnings that such an attack was being planned [Gertz, 2002]. However, any such failure must be at least partly rooted in an inability to escape the accepted paradigm of terrorist behaviour. As David T. Jones, a retired senior US State Department Foreign Service offcer and foreign affairs adviser to the Army Chief of Staff, wrote in 2001: "We were trapped by our paradigm. Ever since 'modern' terrorism began approximately 33 years ago with the assassination of US ambassador Gordon Mein, experts have been constructing programs to handle the endless sequence of hijackings and hostage takings […] experts determined from the psychological patterns of the hostage takers that negotiations would be more productive to resolve the crises and save lives […] a 'book' was devised and experts trained […] The premise was that the hostage takers wanted something negotiable; this time, all they wanted was our lives" [Jones, 2001].

II Cluster B: Managing risks

Successful risk management builds on sound risk assessment.

Governance deficits in risk management occur when the capacity to accomplish one or more of the following functions is lacking: setting goals, developing and evaluating a reasonable range of risk management measures, consulting stakeholders, balancing efficiency and equity, making and implementing policies and decisions, resolving conflicts, and evaluating and monitoring the results of those decisions in the light of actual experience.

Although they have different objectives and perspectives, both the public and private sectors play important roles in risk management. Each has separate responsibilities, but the effective management of many systemic risks requires cohesion between them. They are also prone to some similar deficiencies. For example, pressures to address near-term concerns are prevalent in both sectors. The scope for action of politicians may be shaped by electoral cycles, while corporate actors are constrained by pressure from shareholders to maximise profits and short-term shareholder value. Even leaders of NGOs dedicated to long-term causes may focus on short-term publicity to bolster their visibility and acquire an edge in fund-raising and political influence. Thus, a pervasive challenge in risk management is to bring some long-term perspective to bear on risks when the pressures to focus on near-term concerns are powerful. This is heavily influenced by an organisation's risk culture.

Risk culture refers to a set of beliefs, values and practices within an organisation regarding how to assess, address and manage risks. A major aspect of risk culture is how openly risks can be addressed and information about them shared among a risk community. A risk culture defines an organisation's risk appetite. A good risk culture produces a sound basis for how the competing pressures for risk taking and risk avoidance are resolved. Either pressure, if allowed to dominate decision-making, can be detrimental. For example, public administrators are often criticised for being excessively risk averse, in part because they are more vulnerable to criticism for under-reacting to a risk than for over-reacting. Corporate leaders are often criticised for generating (or neglecting) environmental risks, in part because the damages from environmental risks, which are seen as an externality, are rarely reflected in corporate profit-loss determinations. Shell's experience with its disposal of the Brent Spar platform demonstrates how deficits in risk governance have the potential to significantly affect the bottom line.

Good public and corporate management requires a risk culture that combines a need for enlightened risk taking with a need for prudent risk aversion. Risk culture will vary between individual people, businesses, governments and nations: some will be more risk averse than others, and their level of risk aversion/acceptance will itself vary according to each risk and its impact on them. Good risk governance requires acknowledgement of the lack of a universal risk culture.

A capacity to manage risk is also dependent on the extent to which an organisation has, or can access, the knowledge, skills and technical and financial resources that are needed. Additionally, although confronted with the same risk landscape, governments, regulators and industry may, depending on their goals, prioritise individual risks differently.

In practice, risk management is not linear. Respected, well-intentioned government officials and business risk managers may neglect serious risks, make decisions with unintended outcomes or side effects, or micromanage risk to the point that technological innovations are suffocated. Even large, well-funded organisations are often under-equipped to deal with the challenges of uncertain future risks that arise in complex technological and behavioural systems. Organisations may lack the capacity to anticipate and respond to risks in a preventive, forward-looking manner, and they may lack the flexibility and resilience that is often critical when responding to risks that occur unexpectedly.

In the following pages, some important deficits related to risk management are identified and illustrated with examples from past and current risk governance activities.

B1 Responding to early warnings

Failure of managers to respond and take action when risk assessors have determined from early signals that a risk is emerging

A risk management deficit may arise when signals indicating a risk is emerging are picked up and assessed, but no decisions or actions are taken to prevent or mitigate the risk. The detection of early warnings is useful only if they are then prioritised and followed by a response that is commensurate with the significance of the potential risk. This often implies the need for a prioritisation of risks, to allow the organisation to concentrate on those most relevant to it.

The failure to respond may occur for a variety of reasons. In some cases the information gathered from early warnings and risk assessment is not conveyed to decision-makers. By definition, there is no definitive proof in the case of early warnings, and some professionals will contest the evidence in terms of what it implies and what concrete action should be taken. Related to this point, a failure to respond may reflect "unwillingness to know" if, for instance, the information causes inconvenience or jeopardises particular interests or ongoing plans. Therefore, even if there is an adequate early warning system, there is no guarantee that decision-makers will respond to the signals it provides.

Over-reacting to an early warning is also a potential deficit and can include unnecessary regulation (which may have the effect of stifling innovation) or apprehension (which can provoke counterproductive behaviours).

For example, the measles, mumps and rubella (MMR) controversy of 1998 in the UK led to a reduction in the number of children being vaccinated. A speculative claim was made in the medical journal *The Lancet* that there was a link between the vaccine and autism, and in June 2008 the UK Health Protection Agency reported: "Due to almost 10 years of sub-optimal MMR vaccination coverage across the UK, the number of children susceptible to measles is now sufficient to support the continuous spread of measles" [HPA, 2008]. Ultimately, after completion of numerous epidemiological studies, it was determined that there was no credible evidence of a link between use of the vaccine and autism [Wakefield et al., 1998; IOM, 2004].

Hurricane Katrina

- Failure to respond to early warnings of the hurricane danger to New Orleans resulted in disaster.

The disaster that resulted when Hurricane Katrina hit New Orleans on August 29, 2005 cannot be classified as a surprise. In both the long and the short terms, ample warning of the disaster was met with an insufficient response.

In the long term, the fact that New Orleans was susceptible to a levee collapse was well known and the threat of a hurricane causing such damage even had its own name: "the New Orleans scenario". In the years prior to Katrina, Federal Emergency Management Agency (FEMA) staff ranked the New Orleans scenario as one of the most critical potential disasters facing the US. Nevertheless, concern was not matched by resources to respond, and it took FEMA five years to find sufficient funding for a partial simulation exercise [FEMA, 2004] to model the effect of a hurricane hitting New Orleans. Even then, the funds were insufficient to include an evacuation in the simulation.

In the short term, the National Weather Service issued grave warnings in the days before the hurricane's landfall. Such warnings convinced the governors of Mississippi and Louisiana to declare states of emergency on Friday,

three days before the hurricane reached land. However, the mayor of New Orleans did not order an evacuation until Sunday morning. Similarly, federal responders also lacked urgency, with their initial response after landfall marked by inertia [Moynihan, 2008].

Fisheries Depletion: North Sea herring

- A quick reaction to early warning signals avoided collapse.

A positive example of how previous failures led to improved risk governance is the case of the North Sea herring fshery. This fshery suffered a severe collapse in 1975-76 following failures by regulators to act on early warning signs that fsh stocks were unhealthily low, even though rapid declines in spawning stock biomass and catches composed of 80% juvenile fsh were observed throughout the 1960s. The fshery was closed in 1978 and it took 19 years for stock to recover. Upon the reopening of the herring fshery in 1981, efforts were made to improve the management of fsh stocks [CEFAS, 1999] and, in 1995, when early warning signs again showed that fsh stocks were becoming dangerously low, quick and drastic action – including an EU/Norway agreement on fshery management in 1997 – was taken to avoid another collapse. By 2003, the stock had recovered without requiring even temporary closures of the fshery [Simmonds, 2007]. An important reason for the success was the support from the fshing industry. Why the herring industry in particular has been more supportive of precautionary management actions than many other fsheries can partly be explained by the memory of the earlier collapse [Simmonds, 2007]. But perhaps more importantly, the number of fshing vessels and companies involved in the fshery is small and the businesses are well enough capitalised to beneft from long-term planning.

BSE in the United Kingdom

- Ignoring early warnings increased risks to human health.

The incorporation of rendered meat and bonemeal into animal feed creates a number of risks related to the transmission, recycling and amplifcation of pathogens. Such risks were recognised well before the emergence of BSE. In the UK, the Royal Commission on Environmental Pollution recommended in 1979 that minimum processing standards be implemented by the rendering industries in order to minimise the potential for spreading disease [RCEP, 1979]. The incoming Thatcher government withdrew these proposed regulations, preferring to let industry decide for itself what standards to use. In retrospect, it seems that the failure to act at this point to mitigate the general risk of disease transmission may have had an impact on the later outbreak of BSE, given that the disease “probably originated from a novel source in the early 1970s” [BSE Inquiry, 2000b].

Early signs that BSE might be transmissible to humans were observed by scientists and government offcials throughout the period from 1986 (the time of frst diagnosis in cattle) to 1995 (when vCJD was frst observed in humans). Such observations are noted in, for example, the minutes of a meeting of the National Institute for Biological Standards and Control in May 1988, where it was concluded that “by analogy (with scrapie and CJD) BSE may be transmissible to humans” [cited in van Zwanenberg and Millstone, 2002]. The diagnosis in May 1990 of a domestic cat with a previously unknown spongiform encephalopathy resembling BSE indicated that the disease could infect a wider range of hosts, and in August 1990 BSE was experimentally transmitted to a pig via injection of BSE-infected material into its brain.

According to the BSE Inquiry, “these transmissions were, to put it neutrally, consistent with the possibility that BSE was transmissible to humans” [BSE Inquiry 2000a, Ch 5 and Ch 6: para 644]. Responses to such early warnings of potential dangers to human health (e.g., the Specifed Bovine Offal ban of 1989) were too weak, too late, or badly implemented and enforced. This may have been partly a result of an “unwillingness to know” about the problem, partly because of the economic harm this knowledge would cause the UK beef industry and partly because of failures in institutional capacities and procedures

Regulation of the artificial sweetener saccharin

- Over-reaction to an early warning based on poor scientific evidence led to unnecessary regulation.

Saccharin has been used as an artifcial sweetener in food for over 100 years and controversy over whether its consumption is hazardous to human health has been ongoing for almost as long. It was in 1907, as a result of the Pure Food and Drug Act (1906), that the United States Department of Agriculture frst began to examine saccharin for potential adverse health effects [Priebe and Kauffman, 1980], followed by a failed attempt (due to lack of evidence) to ban saccharin in 1911 [FDA, 1999]. In the 1970s, three studies in which rats were fed high concentrations of saccharin linked the additive to increased rates of bladder cancer [Arnold, 1984]. This was interpreted as an early warning by the Canadian government which, despite the scarce scientifc evidence, took strongly precautionary actionand banned the use of saccharin as a food additive [le Riche, 1978]. The FDA proposed a similar ban in the US, despite saccharin being the only available alternative to sugar at the time [FDA, 1999]. Public outcry spurred Congress to impose a moratorium on the ban to allow for further scientifc study, but with the condition that foods containing saccharin carry the warning label: “Use of this product may be hazardous to your health. This product contains saccharin, which has been determined to cause cancer in laboratory animals” [FDA, 1999].

Following these events, a great deal of scientifc research was done on saccharin, none of which supported the theory that saccharin caused cancer in humans. An extensive review by the International Agency for Research on Cancer concluded that “there is no consistent evidence that the risk of cancer is increased among users of saccharin” [IARC, 1982 cited in Chappel, 1994]. The mechanism by which large doses of saccharin cause cancer in rats is unlikely to be relevant to low-dose human exposures [Ellwein and Cohen, 1990] and, in 2000, the US removed saccharin from its offcial list of carcinogens and repealed the law requiring warning labels on food [Graham, 2003].

B2 Designing effective risk management strategies

Failure to design risk management strategies that adequately balance alternatives

Successful risk management requires setting an objective, designing a strategy to reach the objective, and planning and acting to implement this strategy. Defcits will be found, for example, when there is (a) no clear objective, (b) no adequate risk strategy, or (c) no appropriate risk policy, regulation or implementation plan. When there are two or more objectives (e.g., economic prosperity and environmental protection), defcits can arise from a preoccupation with one objective to the exclusion of the other.

In both the public and private sectors, it is the risk manager’s task to design and implement effective policies and strategic decisions. That task is not easy to accomplish for persistent risks that have defed elimination for centuries (e.g., abuse of alcohol) and for uncertain risks that may be caused by an emerging technology (e.g., nanotechnology). In the case of risks relating to electromagnetic felds, the decision by

some insurance companies to write specifc exclusion clauses [Allianz, 2007] represents a strategic decision to make a trade-off between potential short-term loss due to missed business opportunities and potential long-term liability risks. Regardless of the nature of the risk, effectiveness implies an explicit goal (or goals) for risk management, including systems for measuring progress towards the goal once risk management decisions are implemented. It is not only the public sector which must develop effective strategies for risk management. Whether as the result of government regulation, product liability and personal injury laws or the need to manage risk as part of a broader approach to portfolio management, businesses also need to set and implement risk management strategies that encourage customer satisfaction and shareholder value. Failures imply risk to both the bottom line and a company's wider reputation.

An ineffective regulatory regime may be harmful for the regulated industry as well as the intended beneficiaries of the regulatory programme (e.g., consumers, workers or community residents). For example, there may be a need to put some regulation in place quickly to ensure safety while the opportunities associated with a new technology are explored. Yet, the investment necessary to support technology development may depend on a favourable and predictable regulatory environment. If a regulatory system is not effective, it may be vulnerable to public criticism and to ill-considered reforms that reduce the confidence of investors in new technology, constrain product development and undermine public acceptance of an industrial innovation.

If it is not known whether a regulation will be effective, it may still be appropriate to apply adaptive regulation and evaluate experience. For example, management of novel risks could be done through the use of instruments such as containment, which may limit the use of a new technology (or practice) in space and time to gain more experience with uncertain risks and benefits. Regulation can then be revised on a dynamic basis according to the results of evaluations. For example, it has been recommended that carbon capture and storage systems at coal-fred power plants be regulated in this manner, in order both to minimise risks and to maximise the information that can be applied to later regulatory decisions. When regulatory effectiveness has not yet been measured or proven, an adaptive governance approach using flexible and resilient strategies may be advisable.

BSE in the United Kingdom

- Heightened economic losses as a result of trying to protect both public heath and industrial interests.

It may be argued that the UK government gave greater priority to economic interests than to the protection of public health in the handling of the BSE crisis. For example, the specifed bovine offal (SBO) ban of 1989 was one of the major controls put in place to try to stop the spread of infection. This ban was an effective measure, but it could have been made even more so had economic interests not caused a policy trade-off to be made. As it happened, only those tissues of the lowest commercial value were specifed. Tissues of higher commercial value, or those that would have been very hard to remove and thus have raised abattoir costs, were exempt [BSE Inquiry, 1999]. Therefore, the risks to public health were traded off against the risks to industry, and the chances of human exposure were not diminished as much as they could have been.

The United States' biofuels policy

- Effective with respect to energy security and agricultural development, but not to environmental protection.

Until recently, the great promise of biofuels was that they could increase energy security, decrease greenhouse gas emissions and provide a substantial boost to the agricultural sector – all at the same time. Indeed, all three of these

objectives have been used to justify the biofuel subsidies and mandates pursued by the US government [Rubin et al., 2008]. For example, the Energy Independence and Security Act of 2007 emphasises the first two objectives [Energy Independence and Security Act, 2007, see Title II], while the objective of boosting domestic agriculture is implied by provisions in Title IX of the 2002 and 2008 Farm Bills [US Farm Bill, 2002; US Farm Bill, 2008].

Recent studies on the environmental impacts of biofuels have called into question the compatibility of the three policy objectives. The widespread production and use of corn-based ethanol may be generating more carbon dioxide emissions than the petroleum-based products that are being replaced. In this case, more serious analysis is required to determine whether the objectives are conflicting and, if so, what the right balance should be. In the US, it seems that energy security and agricultural development have overwhelmed consideration of the environment.

Protecting the safety of workers

- Revising regulation to increase its effectiveness.

The US Occupational Health and Safety Administration (OSHA) began operations in 1971. One of OSHA's policy objectives was to reduce the rate of worker injury through enforcement policies that would motivate employers and employees to adhere to established safety standards. This policy objective was explicit, measurable by injury data reported to OSHA by firms and pursued by OSHA through a policy of increased frequency of inspections at workplaces and the imposition of financial penalties for violations. Early evaluations of OSHA's activities (1972 to 1975) found no evidence that the reported injury rate was reduced by the increased risk of inspection and punishment for violations. As a result, OSHA shifted the enforcement policy to emphasise inspections and punishment at workplaces with a history of serious violations. After this shift in practice, it is estimated that OSHA did accomplish a 5-10% reduction (1975-83) in the workplace injury rate [Viscusi, 1992].

B3 Considering a reasonable range of risk management options

Failure to consider a reasonable range of risk management options (and their negative or positive consequences) in order to meet set objectives

A risk deficit occurs when, for reasons such as familiarity, prior use or time constraints, the risk manager selects a favoured option to manage risk without either considering other promising options or adequately justifying and communicating this choice. Such risk management options include, for example, precautionary or conventional risk-based approaches – even, in some circumstances, simply doing nothing. A filtering process is necessary to distinguish the most promising risk management options.

As more than one option is considered, a range of consequences (in addition to relative effectiveness) may be considered. Trade-offs between different consequences (good and bad) may need to be made. The manager should not necessarily pre-determine a preference for one outcome over the other. It may be useful to perform a form of multi-criteria analysis, where all the consequences (including financial, environmental and social benefits and costs) of different risk management alternatives are compared in a rigorous manner. One alternative may be superior with respect to near-term effectiveness, while another

may be superior with respect to technological innovation and long-term effectiveness.

The inappropriate use of a precautionary approach[4] or, vice-versa, the neglect of it, is often seen as a failure in choosing an appropriate risk management option. When decisions must be made about whether an activity needs to be avoided or about the likelihood that this activity is unsafe, scientifc studies are conducted, often leading to the identifcation of uncertainties or thresholds for the probability or likelihood that the activity is unsafe. For example, when these uncertainties are high (or perceived to be high) or when thresholds are low, decision-makers often opt for a precautionary approach. But when there are multiple stakeholders, the differences in their perception of (a) the benefit and cost of avoidance as well as of (b) the accuracy of the information provided by the scientifc study may result in different evaluations, for example of the advisability of taking a precautionary approach which could lead to lost opportunities.

Risk management failures also arise when decision-makers have neglected an entire set of risk management options, such as those that aim to build redundancies and resilience into systems that might be exposed to unknown or uncertain threats. Such actions can reduce system vulnerabilities and allow for a quicker recovery after a hazardous event has occurred [IRGC, 2005]. Building redundancy is thus a risk management strategy which, by increasing resilience, can be a valid approach to responding to uncertain risks and should be among the options to be considered.

Fisheries management

- Drawing from past experience when choosing risk management measures.

Measures to reduce the impact of fshing include quotas, closed seasons and areas, and restrictions on fshing gear. For such measures to be effective there must be a suffcient control and enforcement system in place. Two classes of management tools serve particularly well in providing incentives for responsible fsheries: rights-based management and participatory governance.

It is often important to divide a fsh stock among different nations or other groups. A divisible quota is usually required because other approaches, such as limits on fshing effort, are too diffcult to measure for distribution. Even when an overall quota is set that guarantees ecological sustainability, economic waste is created when fshermen lack secure rights to the resource. In this case their incentive is to catch as many fsh as possible as quickly as possible before the quota is reached. This competitive “race to fsh” can lead to excessive harvests, industry lobbying for larger quotas and generally poor stewardship of fsh stocks.

Rights-based management is a regulatory tool to prevent these drawbacks. It can take many forms, all of which provide a rights holder with a certain share of the fshery whether they are an individual, a cooperative or a community. The greatest economic effciency is achieved when these rights are permanent, secure and transferable. Individual transferable quotas (ITQs) allocate each fsherman a certain portion of the overall catch quota, which he can use or trade. This creates incentives to increase economic effciency in a fshing feet. Examples of rights-based management where the objective is to protect fshing communities are territorial use rights in fshing (TURFs),which specify the right to specifc fshing locations, and community quotas, where fsh quotas are allocated to fshing communities.

Iceland was among the frst countries to introduce ITQs. The ITQ system has led to substantial increases in economic effciency [Arnason, 2006], but also to quota concentrations, causing a concentration of wealth and marginalizing fsheries-dependent coastal communities [Pálsson and Helgason, 1995].

4) IRGC refers to the defnition given in the Rio Declaration on Environment and Development, 1992: Principle 15 states “In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientifc certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.”

The pollock fshery in Alaska is certifed as sustainable by the Marine Stewardship Council. The fshery is formed by cooperatives with pre-set quota shares. Although these rights have been an incentive to increase economic investments and gains, they do not provide sustainability on their own. The North Pacifc Fishery Management Council, which also set regulations for the pollock fshery, provides precautionary fsheries management with relatively low harvest rates and strict bycatch regulations. Also, each pollock vessel has complete observer coverage so that there are no compliance problems [Witherell et al., 2000].

Managing pesticides

- Regulation as incentive or constraint – how different options influence industrial innovation.

Pesticides are intentionally toxic, which calls for regulation to ensure that products are safe, effective and of high quality. However, regulation can itself induce other types of risks because it may constrain innovation.

Pesticide regulations can be categorised along two scales: *enabling* (providing encouragement or inducements to undertake a desired course of action) versus *constraining* (creating disincentives for undertaking undesirable actions); and *indiscriminate* across a range of products versus *discriminating* among products on some policy basis [Tait et al., 2006; Chataway et al., 2006; Tait et al, 2001].

The US Food Quality Protection Act (FQPA) 1996 is both enabling and discriminating. It created a “fast track” for regulating pesticides with a better health or environmental safety profle than products currently on the market. This enabled companies with such products to gain an advantage over others and changed the behaviour of some companies. It led to pesticide candidates with better properties displacing others in the queue for registration, so that pesticides without these attributes could not be registered within a reasonable timescale. This was constraining for companies that did not have these “better” products in their pipelines, and acted as a stimulus to move their research and development in this direction.

The European Drinking Water Directive (DWD) (80/778/EEC, now replaced by the EU Water Framework Directive) was constraining and indiscriminate. As framed in 1998, it set a very low limit (0.1ppm) on the permitted level of contamination of drinking water reservoirs by any pesticide. It acted as a constraint, imposing penalties rather than creating an incentive as in the FQPA. It also did not discriminate between pesticides with a difference in toxicity of up to 1,000-fold, and focussed attention on the important, but less appropriate, characteristic of mobility in soils, prompting companies to reject any such chemicals from their research and development pipelines.

Managers in Zeneca Agrochemicals in 1998 described how the FQPA and the DWD had affected their decision-making on pesticide development. The company’s strobilurin fungicide was the frst product to be registered under the FQPA fast track as a safer product, but narrowly escaped being rejected from the research and development pipeline because of its mobility in soil.

B4 Designing efficient and equitable risk management policies

Inappropriate risk management occurs when benefits and costs are not balanced in an efficient and equitable manner

One of the key shortcomings of risk management is that policies or decisions may be inefficient, inequitable or both.

The most common measure of efficiency, drawn from the field of "welfare economics", is maximisation of net benefits (benefits minus costs). In this strict form of benefit-cost analysis, the consequences of risk management measures are quantified and expressed in common units (usually a monetary measure). The underlying principle is that, when two or more measures are compared, the more efficient one has the highest estimate of net benefits. Unlike business economics, which tends to maximise profit, a "societal" benefit-cost analysis includes all forms of benefits and costs, including those affecting human health and the environment. In recent years, the European Commission, the UK and the US have all used benefit-cost analyses to inform public decisions about air quality and climate-protection programmes.

When the key consequences of a measure cannot be quantified and expressed in monetary units, the findings of a benefit-cost analysis are less clear; decision-makers must use judgement to weigh the unquantified – and sometimes intangible – benefits and costs. This process of weighing qualitative as well as quantified benefits and costs is sometimes called "soft" benefit-cost analysis and it is often more practical than purely numeric forms of analysis[5].

Another insight from efficiency analysis, called cost-effectiveness, is that uniform standards may be more costly and less effective than market-based instruments such as taxes on pollution or programmes that permit companies to buy and sell pollution permits under a national, regional or international cap on total pollution. Building on the experience of the EU's cap-and-trade programme to control carbon dioxide, the Obama administration has recently proposed that a similar programme to control greenhouse gases be enacted in the US.

However, risk management policies are not determined solely on the basis of efficiency, as positive efficiency does not necessarily include an equitable sharing of costs and benefits. Various notions of equity, such as intra- and inter-generational equity (sustainability) or concepts of distributive justice (ethical acceptability), are employed to determine whether the distribution of winners and losers from risk management is acceptable.

Applying a theory of "justice" pioneered by the Harvard philosopher John Rawls, risk managers sometimes seek equity by asking what impact a risk management measure will have on the least advantaged members of society (measured by income, social class or race/ethnicity). Even if a measure is efficient on a society-wide basis, it may be judged inequitable if it imposes more burdens than benefits on the most vulnerable populations or the least advantaged members of society. In the field of environmental policy, concepts of equity are often subsumed under the heading "environmental justice".

A different notion of equity concerns situations where the costs of a risk management measure are imposed on a group of people or nations that did not create a risk and do not deserve to be burdened. For example, the international community recognises that it is inequitable for citizens of developing countries to pay the costs of programmes to reduce greenhouse gas emissions when it was the growth of the developed world that led to the predicament that now troubles the globe. It is generally agreed that wealthier countries should subsidise the application of green technology to facilitate sustainable development in the developing world.

Equity arguments in risk management are difficult to evaluate because no citizen, region or country wants to be made worse off by risk management measures. Losers from risk management will have a tendency to see their losses as inequity, while winners will perceive their gains as deserved. It is therefore important to perform careful analysis of equity arguments even though there is no objective yardstick by which to

5) In addition, formal methods of decision analysis such as multi-criteria analysis (MCA) or multi-attribute-utility-analysis (MAU) can assist decision-makers to evaluate intangible outcomes [Skinner, 1999].

evaluate equity, and justifcation of gains and losses inherently involves some degree of subjectivity.

The most perverse risk management measures are those that compromise both effciency and equity, with no corresponding benefit to justify their continuation. The tools of regulatory impact assessment (RIA) have been developed and employed by many governments to assist in the identifcation of policies that have superior consequences for both effciency and equity. According to the OECD, most developed countries in the world now have some RIA process in their national governments. A small but growing number of countries, as well as the European Commission, have created centralised oversight units to issue guidelines for, and to review the quality of, major impact assessments.

The Kyoto Protocol

- Issues of efficiency and equity were central to concluding the Kyoto agreement on greenhouse gas emissions.

The problem of equity and climate change is two-fold. The rich, developed countries have produced the majority of greenhouse gas emissions and have special responsibility for the risks the entire world is now facing. And

may be perfectly conceived and formulated, and well-adapted to a particular risk, and regulations may be well-balanced, but little will be accomplished if they are not implemented and enforced.

There are sometimes perverse incentives for policymakers to create risk management policies that are not implemented. Policymakers may wish to be seen as "acting" when in fact they lack the resources, time or organisational capacity to ensure implementation. In some cases, policies may be implemented only symbolically, and implementation may be (quietly) taken for granted and not even monitored.

BSE in the United Kingdom

- Effective regulations were successfully designed, but flawed implementation or lack of enforcement led to a negative outcome.

Two of the most important regulations introduced during the BSE crisis were the ruminant feed ban and the specifed bovine offal (SBO) ban. Implementation was defcient in both cases. The feed ban, while an effective measure, was not implemented as swiftly or effectively as it could have been: it was passed on June 14, 1988, but not implemented until July 18 – a fve week delay that allowed many thousands more animals to become infected. The SBO ban of November 1989 was an even stronger illustration of implementation and enforcement failure. Because there was a

B6 Anticipating side effects of risk management

Failure to anticipate, monitor and react to the outcomes of a risk management decision in the case of negative side effects

Changes in one part of a complex system can have an impact on and beyond the other components of the system. Successful risk management requires *anticipation* of both the intended and unintended consequences of decisions. For example, well-intentioned efforts to protect the environment and to avoid other secondary risks from nuclear power may have strengthened the business case for building new coal-fred power stations, with many adverse impacts on environmental quality. Similarly, biofuel policies designed to strengthen energy security may have negative impacts elsewhere, such as on food prices or indirect greenhouse gas emissions.

A corollary of this governance defcit is the frequent failure to *monitor* the effects of decisions, not just for effectiveness but for plausible adverse side effects and ancillary benefts. Contingency plans need to be prepared that can be put into action quickly should the measures fail to meet their targets or have unintended negative side effects. Without appropriate monitoring and evaluation of policies, the proper design and implementation of contingency plans can be expected to suffer.

Monitoring the use of clozapine

- Careful monitoring of reactions to this effective drug allows it to remain on the market, despite its potentially dangerous side effects.

Austrian and German clinicians began investigating the drug clozapine in the mid-1960s. A potent anti-psychotic, clozapine was atypical in that it showed few if any of the neurological side effects common to most anti-psychotic medication [Hippius, 1989]. It was introduced to the market in Europe in 1973 [BMJ, 1991]. However, reports from Finland in 1975 soon raised concern about its risks, as 16 out of 2,260 patients developed agranulocytosis (an acute, severe and dangerous decrease in the number of white blood cells), with eight subsequently dying [Naheed and Green, 2000]. The manufacturer of the drug, Sandoz, subsequently withdrew the product from the market, judging the risks (1-2% risk of agranulocytosis, and the company's associated liability) to be too high.

Because clozapine had been shown to be extremely effective against conventional treatment-resistant schizophrenia, ameliorating symptoms and decreasing the suicide mortality rate, there was pressure from psychiatrists to reintroduce the drug. Many felt that its benefts outweighed its risks [Naheed and Green, 2000]. Such pressure led to the reinstatement of drug trials, this time under close haematological monitoring – "the real question is not whether agranulocytosis occurs, but how to prevent fatalities amongst those developing such disorders. Regular blood monitoring makes this possible" [Hippius, 1989]. Following successful trial data, clozapine was reintroduced in the European market and approved for the frst time in the US in 1990.

Given the previous experience, a risk management programme with strict requirements for blood monitoring was made mandatory in many countries. In the US this was known as the "no blood, no drug" programme. It mandated physician, pharmacist and patient registration, a patient database, ongoing compliance monitoring and feedback, and weekly complete blood cell counts for patients, both prior to and while receiving the drug [Liederman, 2008]. This programme is regarded as having been successful and has been adapted over the years on the basis of real-world data and patient experiences [Mechcatie, 2005].

CFCs and ozone depletion

- Monitoring the consequences of the use and the banning of CFCs.

In the 1930s, when chlorofluorocarbons (CFCs) were first employed on an industrial scale, a lack of comprehensive scientific knowledge made it impossible to anticipate that these chemicals would affect stratospheric ozone. Rather, they were considered "non-toxic, stable and harmless in every way" [Mullin, 2002].

However, once scientists made the discovery in 1974 that the breakdown of CFCs in the stratosphere was causing the depletion of stratospheric ozone [Molina and Rowland, 1974; Cicerone et al., 1974], efforts to monitor these consequences of CFC production were quickly mounted. Indeed, monitoring of anthropogenic CFC emissions and of ozone loss and recovery has been carried out systematically and carefully since the late 1970s, using ever more sophisticated technologies. The discovery of the ozone "hole" over Antarctica in 1985 heightened the already growing international concern about ozone depletion.

In 1987, the Montreal Protocol on Substances that Deplete the Ozone Layer was signed, leading to regulated production and a scheduled phasing out of ozone-depleting substances (entry into force January 1, 1989). As a result of the Protocol's regulations, the combined levels of ozone-depleting gases in the stratosphere decreased by 8-9% as of 2005 from their peak values observed in 1992-1994 [WMO et al., 2007]. Although emissions reductions for many ozone-depleting substances have been significant, atmospheric concentrations decrease much more slowly because of the long atmospheric lifetimes of some of these compounds, which can be 50-100 years [WMO et al., 2006]. It is expected that, because of the "resounding success" of the Montreal Protocol, CFCs and other harmful emissions could fall below the levels that produce an ozone hole around 2070 [NASA, 2007].

To ensure that this goal remains possible and that actions continue to be effective, continual monitoring of compliance with the Protocol, of emissions levels, and of ozone depletion and recovery must continue.

B7 Reconciling time horizons

An inability to reconcile the time frame of the risk with the time frames of decision-making and incentive schemes

As mentioned in the introduction to this section, business and politics are often dominated by short-term considerations. Yet risk issues have a variety of time profiles. Some become apparent only after a long period of time (e.g., chronic disease after a certain latency period), some strike suddenly with various degrees of warning (natural disasters), some start slowly but may escalate rapidly in epidemic fashion (e.g., AIDS) and some are so persistent that they breed neglect due to familiarity (e.g., alcohol abuse). Risk managers, as they grapple with risk issues, must encourage time horizons for risk management action that are aligned with the nature of the risk and its consequences, even though those perspectives may not be natural or appealing to politicians or business leaders. This trade-off is particularly difficult to resolve with issues such as climate change, where the effects of decisions made now will not be realised for many years.

Arguably the most pervasive deficit is a tendency to ignore long-term risks and costs relative to the day-to-day needs that seem to be – and sometimes are – urgent. A related tendency is to look for simple "quick fixes" to complicated, long-term challenges that may require fundamental changes in public attitudes, behaviours and institutions (e.g., sustainability and climate change).

Asbestos

- Long-term health damage and costs to industry from asbestos-related disease were incurred because of the short-term orientation of policymakers in industry and government.

In the UK, accounts of asbestos-related health hazards were recorded as early as 1898 and the first dust control, medical surveillance and compensation regulations in the world were introduced in 1931. Unfortunately, these rules were only partially enforced as concerns for the near-term economic viability of the industry contributed to decades of delay in response to early warnings of risk. Licensing regulations and exposure limits were ultimately introduced in 1984 and a full ban on asbestos was implemented in 1999 [Gee and Greenberg, 2002]. It has been estimated that "a surge in asbestos-related claims over the coming decades could land British insurers and employers with a bill of up to £20bn" [Jones, 2004].

It turns out that exposure to asbestos is associated with an increased risk of developing lung cancer and mesothelioma (a relatively rare, and deadly, cancer of the thin membranes that line the chest and abdomen [Collins, 2008; National Cancer Institute, 2009]). Such cancers have a long latency period, from 10 to 50 years after the time of first exposure to asbestos.

This long latency period contributed to a period of complacency about asbestos exposure, especially since politicians and regulators were concerned about the near-term benefits of asbestos-related profits for employers, jobs for workers and tax-related revenues for government. With the benefit of hindsight, it is apparent that the trade-offs that were made were short-sighted. In effect, fear of short-term costs led to much larger long-term costs for both industry and government as early warnings of health risks were discounted and public health responses delayed. The failures were not unique to the UK. They happened as well in the US and other regions of the world.

The Stern Review on the Economics of Climate Change

- The difficulty of weighing the near-term costs and long-term benefits of aggressive international policies to slow global climate change.

In order to successfully prevent (or slow) the global climate change caused by man-made emissions of greenhouse gases, governments around the world are considering adoption of costly policies that may reap significant long-term environmental and economic benefits. Economic analysis of such policies must include an appropriate discount rate – an interest rate employed so that future benefits and costs may be directly compared to current benefits and costs.

In October 2006, the UK government released the "Stern Review on the Economics of Climate Change", a report for policymakers that made an economic case for "strong and early" action – including costly actions – to prevent global climate change [Stern et al., 2006]. Lord Stern's findings and conclusions triggered significant controversy for a simple reason: critics challenged his premise that an extremely low rate of discount should be applied to impacts (benefits or costs) that occur dozens or hundreds of years in the future. While standard economic analyses employ real (inflation-adjusted) annual discount rates of 2-7%, the Stern Review chose a very low discount rate of 0.1% [Dasgupta, 2006]. Professor Richard Nordhaus of Yale University, another eminent economist, argued that the Stern Review should have used discount rates up to and beyond 3% [Nordhaus, 2007; Nordhaus and Boyer, 2000]. Nordhaus and others believe that a very low discount

rate acts to discourage near-term investments that are in the interests of the world's currently impoverished populations. Only by relying on such a very low discount rate, Nordhaus argues, was the Stern Review able to justify such a large near-term investment in policies to curb greenhouse gas emissions. Stern counters that use of higher discount rates has the mathematical effect of short-changing the welfare of future generations.

B8 Balancing transparency and confidentiality

Failure to balance two of the necessary requirements of decision-making: transparency, which can foster stakeholder trust, and confidentiality, which can protect security and maintain incentives for innovation

When communicating information about the risk issue and the decisions taken on how to manage it, the need for either transparency or confidentiality will vary. An excessive focus on confidentiality may reduce trust in risk management and in decision-makers by raising suspicion that the shield of confidentiality is being used as a power lever (e.g., by government and/or industry) to advance or protect particular interests without adequate justification. On the other hand, excessive transparency may not respect the need to protect legitimate interests (e.g., the privacy interests of individual citizens). For example, a citizen's desire to keep his or her health records confidential is a legitimate claim of confidentiality in many societies. Likewise, the protection of business secrets in competitive markets, where innovations can be the subject of piracy, is also seen as necessary for a well-functioning, innovative economy. And, the requirements of national security and defence or a desire to avoid public panic may justify a prioritisation of confidentiality over transparency.

The general trend in public and corporate governance, however, is towards more release of data, more transparent reporting and fuller accountability, while maintaining some confidentiality under compelling circumstances. Terrorism is a relevant example. In an initiative tailored to the requirements of risk governance, the UK government has addressed the problem of balancing transparency and confidentiality by issuing "Principles of Managing Risks to the Public", which includes the promise to give an "appropriate" answer to the public in all situations:

> Government will make available its assessments of risks that affect the public, how it has reached its decisions, and how it will handle the risk. […] When information has to be kept private, or where the approach departs from existing practice, it will explain why. Where facts are uncertain or unknown, government will seek to make clear what the gaps in its knowledge are and, where relevant, what is being done to address them. It will be open about where it has made mistakes, and what it is doing to rectify them. [HM Treasury, 2005]

The recent emphasis on greater transparency in communication perhaps reflects lessons learned from past experiences where inadequate communication and explanation of risk management decisions led to negative outcomes. For example, this occurred during the handling of the BSE epidemic in the UK over the period 1986-96. In this case, there was a disproportionate emphasis on confidentiality in order to protect the interests of industry and avoid public panic, which ultimately led to the risks being downplayed. This resulted in a serious erosion of public trust in the government.

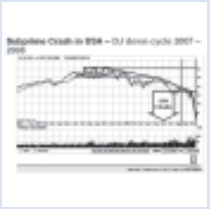
Enron

- A deliberate lack of transparency in accounting practices put the entire company at risk.

The lack of transparency in Enron's accounting practices was so great that it was able to convince investors, shareholders and the market in general that the company was on frm ground. In truth, Enron had a huge amount of debt that its incredibly complex and opaque accounting practices had allowed it to hide in off-balance-sheet overseas entities. This, combined with its use of "mark to market" accounting (where projected future earnings from long-term contracts were treated as current income), greatly infated its reported earnings, so that its sudden bankruptcy shocked the market. The lack of transparency in Enron's accounting and auditing was one of the major failures of corporate governance implicated in the Enron scandal, offering an example of using fnancial innovations within modern corporations to an extent that is neither sustainable nor ethical [Dembinski, 2006].

The subprime crisis in the United States

- A lack of transparency in financial markets was a contributing factor to the crisis.



A build-up of opacity occurred in fnancial markets prior to the recent subprime mortgage crisis. Home and car loans were offered to millions of people with weak credit records and insuffcient incomes and assets. In the years preceding the recent crisis, fnancial products became less transparent about the risks of the underlying loans that were packaged together and resold around the world. Managers in the fnancial system made decisions about investments based on information which was not transparent about risk and did not conform to expected regulatory standards. Ratings agencies assigned superb ratings to highly vulnerable investments. Global banks took on risks that they did not declare until they were forced to analyse and evaluate them and take responsibility. In such opaque markets, it should not be surprising that investors tended to panic when the troubles were disclosed, just as they did during past fnancial crises [Zandi, 2009].

B9 Organisational capacity

Failure to build or maintain an adequate organisational capacity to manage risk

Effective risk management depends on people and organisations that can mobilise resources, build consensus and translate ideas into practical risk policies. Such managerial effectiveness relies upon an adequate organisational risk management capacity. There are many dimensions to such capacity.

IRGC has summarised these dimensions as comprising three distinct but complementary dimensions: "assets", "skills" and "capabilities" [IRGC, 2005]. Assets include knowledge, fnancial and human resources, organisational structures and processes, and the organisational integration that deploys these assets most effectively. Skills are the ability of organisations and their managers and staff to adapt their assets to deal with changing and often dynamic situations. Capabilities constitute the framework in which the assets and skills can be best exploited, including the network within which an organisation cooperates and communicates in the handling of risks, and the overall governance regime under which that network operates.

At the most intangible level, organisations must have a culture that recognises the value of risk management to the long-term viability of the organisation and society,

despite both the controversies created when risks are managed explicitly and the costs that preventative measures may represent, with no direct return on expenditure. Such a culture must show awareness of risk and its consequences, and be supportive of responding adequately to risks even during the early stages of their development.

Organisations with a sophisticated approach to risk governance also recognise the importance of communicating and consulting with stakeholders, and know which methods of stakeholder involvement are most appropriate for a particular risk management problem [Renn, 2008]. We have argued (see A4) that risk assessment can be enhanced through including within the process lay stakeholders and the knowledge they can communicate. An extension of the concept of "organisation" to include stakeholders within risk management, particularly of risks that are inherently complex, uncertain or ambiguous, can bring benefts that include achieving acceptance and implementation of the management decision [IRGC, 2005].

Hurricane Katrina

- A well-intentioned reorganisation to combat terrorism curtailed a federal agency's capacity to respond to natural disaster.

After 9/11, the US Federal Emergency Management Agency (FEMA) was reorganised to become a part of the new Department of Homeland Security (DHS). Because of the heightened focus on terrorism, FEMA had its powers and resources downgraded as DHS stepped up counterterrorism efforts. Some funds that had been allocated to FEMA by Congress were redirected to other parts of DHS to refect its new priorities, and FEMA began to suffer serious budget shortages. Personnel shortages were one consequence of this and, prior to Hurricane Katrina, the Agency had a 15-20% vacancy rate and was relying heavily on temporary employees. As a result, when Katrina hit, FEMA did not have suffcient organisational capability to respond effectively [Senate Report, 2006; House Report, 2006].

Health-care workers and the Toronto SARS outbreak

- The importance of communicating with stakeholders.

When a previously unknown infectious disease was frst identifed in a Toronto hospital in March 2003, the Ontario Public Health Branch immediately prepared a letter raising an alert and advising that precautions (such as wearing gloves, gowns, eye protection and masks) be taken by all health-care workers when dealing with suspected cases. However, this letter was sent only to physicians and not to other equally important front-line responders, such as nurses, ambulance services and paramedics. Indeed, the relevant unions had no knowledge that any of this information was communicated to health-care workers in any health-care facility. Overlooking the "critical need to listen to nurses and other healthcare workers and to more effectively communicate with them in hospital and other settings" signifcantly compromised efforts to bring the SARS crisis under control [Campbell et al., 2004]. Important decisions concerning health-care workers, such as the controversial directive to wear ft-tested N95 masks, were made without consulting the most important stakeholders – those who would have to implement them. The ft-testing of masks was felt by health-care workers to be operationally impossible, and they received no support to help them comply with the directive [Health Canada, 2003].

B10 Dealing with dispersed responsibilities

Failure of the multiple departments or organisations responsible for a risk's management to act cohesively

This deficit can occur where complex interconnected systems require multi-actor and multi-level governance structures but no single entity has overall responsibility, or one entity has conficting responsibilities. Overlapping, shared or unclear responsibilities, with poor communication and cooperation, can mean that important decisions will not be taken or will not be implemented.

Governments and large corporations tend to create fragmentation in risk management through complex and compartmentalised organisations. They often create separate functional groups that generate "silo thinking" about risk (e.g., one unit concentrates on air pollution, another on water pollution, and so forth). Although fragmentation serves some useful purposes (e.g., specialisation of labour), it invites unproductive situations where no one has accountability for the overall problem and where sub-departments are disinclined to consult with each other, share information or work together as a problem-solving team. Things can fall through the cracks.

Dispersed responsibilities occur when actors at different levels are required to work together, for example when the federal, regional (states) and local (municipalities) governments share responsibilities, or when multi-disciplinary and global teams in industries and/or government work together. They may also occur when government, business and civil society have different, potentially overlapping responsibilities, as for example in the electricity sector, where different companies act as power producers, retailers and managers of unbundled transmission and distribution networks, with governments or government agencies as regulators.

Within organisational structures, different ministries or different operating companies of the same group may have conficting interests and objectives (as happened, for instance, during the UK government's handling of the BSE crisis or during Shell's Brent Spar problem).

Dispersed responsibilities are likely to be prevalent on an international scale where nation-states have sovereign powers, but risks in one country or region of the globe have trans-boundary impacts. International treaties (and less formal mechanisms) are sometimes assembled to address trans-boundary issues, but the international organisations that are created to manage such risks suffer from some of the same deficits that afflict national and local organisations.

In theory, risk governance frameworks should assign responsibilities for risk management and hold managers accountable for performance. For example, the British government states that "those who impose risks on others also bear responsibility for controlling those risks and for any consequences of inadequate control" [HM Treasury, 2005] – a principle that holds in all countries whose laws include the duty of care. In reality, though, it is not always evident who is or was responsible for decisions and policies. Finding the right balance of responsibility in a multi-actor, multi-level process (for example, when public and private organisations, including NGOs, contribute to a failed risk management strategy) and establishing effective communication between dispersed organisations are therefore crucial challenges.

Swiss-Italian blackout

- The division of responsibilities between countries and companies created challenges that complicated risk governance.

The efficient and secure transmission of electricity between many European countries relies on cooperation between separate, independent transmission service operators (TSOs) and their compliance with standards established by the Union for the Coordination of Transmission of Electricity (UCTE). The responsibility for managing the interconnected European electricity network is therefore shared between the TSOs.

On September 28, 2003, a power blackout affected more than 56 million people across Italy (except Sardinia) and parts of Switzerland. The economic cost of the blackout has been estimated at US$139 million [IEA/OECD, 2005].

The initial incident was a trip (caused by a tree flashover) of the 380kV Mettlen-Lavorgo line in Switzerland. High loading had increased the line's temperature, causing it to sag close to nearby trees. In turn, this increased the load on a cross-border line, Sils-Soazza, which could not safely maintain such a load for more than 15 minutes [UCTE, 2004]. Rather than ask Italian operators to take action to restore N-1 security to the system (the N-1 rule being part of the UCTE standards), the Swiss operators tried, unsuccessfully, to re-close the line, and then telephoned the Italians to request that they reduce their power imports by 300MW. It is not clear whether the Swiss informed the Italians (who had no way to see what was happening in the Swiss system) about the outage of the Mettlen-Lavorgo line [Schläpfer and Glavitsch, 2006].

Steps taken by both operators failed to prevent the trip of the Sils-Soazza line. This second trip created overloads on remaining lines, which caused the remaining interconnections to trip and isolated Italy from the European network. This destabilised the Italian system and tripped several of its domestic generators, causing the blackout. The loss of Italian demand also led to sharp frequency increases elsewhere in the UCTE system, necessitating emergency responses from other European system operators in order to quarantine the effects of the outage [IEA/OECD, 2005].

Subsequent investigations of the blackout found that the underlying problems that led to the incident were largely a result of how responsibilities for cross-border exchanges of electricity were shared between TSOs. They recommended improved coordination between the TSOs (including joint operator-training programmes) and better compliance with UCTE standards, which should become legally binding [SFOE, 2003; UCTE, 2004; CRE and AEEG, 2004].

BSE in the United Kingdom

- Assigning the same ministry responsibility for both industry promotion and risk management invites management deficits.

The UK Ministry of Agriculture, Fisheries and Food (MAFF) was responsible for promoting the economic interests of the agricultural community – in this case the cattle farmers, abattoirs and renderers – as well as dealing with matters related to food safety. Given the heavy influence of the industries involved, risk management might have been more successful had these two responsibilities been separated. As it was, MAFF could not implement measures related to food safety without hurting industry interests. This goes some way towards explaining its initial "unwillingness to know" about the extent of the problem and its weak policy response [Dressel, 2000]. After the BSE crisis, this split role was addressed by the creation in 2000 of a separate body, the Food Standards Agency, to deal with food safety risks to public health [van Zwanenberg and Millstone, 2002]. The success of the new institutional arrangement has yet to be put to the test.

Hurricane Katrina

- Confusion of responsibilities between federal, state and local responders.

The multi-level nature of crisis response in the US assumes a gradual expansion of government involvement as local and then state responders are required to give assistance. However, this “pull” approach encounters difficulties when state and local capacities are damaged or overwhelmed. In the case of Katrina, federal responders waited too long for specific requests for aid from state and local authorities instead of taking a more aggressive “push” approach.

Dispersed responsibilities also complicated efforts to set up a central command. Confusion about responsibilities was increased by the existence of three major federal operational commands: the Joint Field Office and Federal Coordinating Officer; the Principal Federal Official; and Joint Task Force Katrina. The lack of a clear directing authority encouraged responders to “freelance” without coordinating with appropriate authorities. For example, the heroic efforts of the Coast Guard in search and rescue have been rightly praised, but there was little effort to coordinate with FEMA, state agencies, the National Guard or the Department of Defense, which were also running search operations. As a result, there was duplication of effort in some neighbourhoods and a lack of attention to others.

The network of responders also includes NGOs, and it is important to recognise the additional challenge of coordinating their activities [Moynihan, 2008]. In Katrina the Red Cross worked closely with FEMA, but still had difficulties in coordination. The Red Cross communicated logistical needs to FEMA, but found that FEMA often did not supply reliable information, failed to deliver promised supplies or delivered inadequate amounts too slowly. Such problems are indicative of more serious challenges in incorporating NGOs into the response network.

B11 Dealing with commons problems and externalities

A lack of understanding of the complex nature of commons problems and consequently also of the specific risk management tools required to address them

The term “commons” applies to goods or resources to which all members of a community have rights or access. The so-called “Tragedy of the Commons” [Hardin, 1968] describes a dilemma in which multiple individuals acting independently in their own self-interest can ultimately destroy a shared resource even though it is in their joint long-term interest to preserve it. Given that many common resources (e.g., the atmosphere and water bodies) are crucial for the Earth’s life support systems, their uncontrolled exploitation may create serious long-term risks. Local fsheries or smog pollution are examples of commons problems within a region or nation-state. International fsheries or greenhouse gas emissions are examples of cross-border issues with more complicated management concerns.

Common goods or resources may fall under a very limited system of property rights, or such a system may be absent. One example of assigning property rights to a common property resource is the development of “cap and trade” schemes to control the amount of carbon dioxide (and other greenhouse gases) emitted into the atmosphere. Managing commons problems can be difficult because the protection of global commons often demands relinquishing short-term economic or other benefts in exchange for protection of shared resources. Other solutions to the commons problem relate to governmental oversight and monitoring (which tend to lead to high control costs) or voluntary agreements among all users to refrain from overusing the resources. If such an agreement can be established, free-riders avoided and the sustainable

yield per user clearly defined, such arrangements can be both very effective and efficient.

When commons problems entail cross-border or planet-wide impacts, international cooperation is generally required for effective management. Such cooperation is notoriously difficult to achieve but attempts are being made (e.g., the Kyoto Protocol to the UNFCCC and the UN Convention on Biological Diversity). The uneven or ineffectual experience of international agreements has demonstrated how difficult it is to deal with commons problems.

The Montreal Protocol

- An example of successful international cooperation to address a commons problem: depletion of the stratospheric ozone layer.

One positive example of managing a commons problem in a cooperative and coordinated way is the adoption of the Montreal Protocol on Substances that Deplete the Ozone Layer [UNEP, 2000]. This Protocol called for the regulation (and phasing out) of CFCs and other substances which react in the upper atmosphere to deplete ozone. Because the ozone layer protects the Earth's surface from ultraviolet radiation that is harmful to plant and animal life, and because these chemicals were widely used by industries in many countries, action had to be international and include participation by governments, industry and scientists. All major stakeholders played a role in international negotiations and, despite their different perspectives and interests, were able to cooperate effectively.

> The push for binding regulation on CFCs was initiated by the Toronto group of like-minded governments and followed up by the United Nations Environment Programme, which convened the inter-governmental negotiations in 1982 that led to the Vienna Convention on Protection of the Ozone Layer, signed in 1985 [Benedick, 2004]. The Montreal Protocol to this convention (signed in 1987 and in force since 1989) imposed a strict timetable for the phasing out of ozone-depleting substances.

The Montreal Protocol was a ground-breaking agreement and, according to Kof Annan, "perhaps the most successful environmental agreement to date" [UNEP, 2003]. It was the first international environmental agreement to adopt a precautionary strategy of immediate action before all the scientific ramifications were understood. It imposed trade sanctions to achieve its goals and differentiated between developed and developing countries in recognising the origins of the problem and distributing responsibility for solving it [UNEP, 2005]. It also gave industry an incentive for innovation by opening the market to higher value-added patented chemicals to replace CFC commodity chemicals [Tait and Bruce, 2004]. The "fundamental shift in industrial processes" led industry to develop a CFC substitute in only three years, a result that "would have been inconceivable without international regulation" [citation in DeSombre 2000/1; see also Mullin, 2002].

The Reduced Emissions from Deforestation and Forest Degradation scheme

- Using financial incentives as a tool to address a commons problem.

Forests play an important role in the global carbon budget, acting either as sinks or sources of CO_2 emissions. The effects vary globally as a result of differences in soil, tree type, tree cover and other factors. Deforestation (which is estimated by the UN Food and Agriculture Organization at 13 million hectares per year for 1990-2005 [FAO, 2005]) and forest degradation result in substantial reductions in forest carbon stocks and significant increases in emissions.

Some have referred to the destruction of the world's forests as a tragedy of the commons even though the forests may be privately owned. Many externalities result from the private benefit earned from deforestation, leading to public costs in terms of lost ecosystem services.

Payments for Environmental Services (PES) have been proposed as a means of assigning an economic value to common goods and services, and making direct, contractual and conditional payments to local landholders and users in return for adopting practices that secure ecosystem conservation and restoration [CIFOR, 2005].

> The Reduced Emissions from Deforestation and Forest Degradation (REDD) scheme, agreed on in principle at the Bali Conference of the Parties to the UNFCCC in December 2007, includes provisions for positive financial incentives for the reduction of deforestation and forest degradation (specifically, for reduction of the greenhouse gas emissions that result). These payments compensate landowners for the loss of income they would have received from deforesting. REDD may thus be seen as a form of PES.

REDD is concerned not only with maintaining services contributed by forests such as carbon sequestration, sustaining biodiversity, supporting the hydrological cycle and helping to build soils, but also with the social consequences of its actions. REDD aims to ensure that all its associated measures and actions address the needs of the approximately 1 billion people who depend directly on forests for their livelihoods, incorporating standards to ensure adequate protection for the rights of local people and indigenous communities [UNFCCC, 2008].

B12 Managing conflicts of interests, beliefs, values and ideologies

A conflict may be negotiable or irreconcilable, and risk managers must have the capacity to distinguish between the two

Management of risk is not a purely technical task; it may entail accepting or seeking to resolve fundamental conflicts between individuals, societal groups, businesses and governments. Broadly speaking, those conflicts may relate to differing interests that are typically tangible or material in nature (such as economic interests), to commonly held beliefs about the nature and the consequences of risks, or to basic values such as social justice or ecological sustainability. They may also relate to differing ideologies ("views of the world"), whether those ideologies are grounded in religion, ethics, philosophy, culture, tradition or politics. Conflicts and tensions can arise at multiple levels, and deficits may occur when the determination of "who is at risk?", "what are the priorities for response?" and "whose priorities are these?" are not made clear or are the subject of disagreement.

The underlying motives that drive conflict may be exaggerated by the concerns or personalities of particular leaders, including the varying levels of trust that people have in them, as well as by how comfortable people are with the processes of negotiation, compromise and compensation.

Confusion about the underlying motives of protagonists can occur. For example, advocates with a material interest in the issue may represent their position as rooted in a philosophical principle that cannot possibly be compromised. Likewise, decision-makers may dismiss or even disbelieve a stakeholder's honest claim that a concern flows from adherence to an unusual religious or ethical belief. It may therefore be a challenge for the risk manager to accurately determine what the motives of stakeholders are. Thus, the imperative of conflict resolution rests to some extent on the manager's critical need to gather information about the views, interests and ideologies of the key stakeholders.

In handling conflicts, it is often crucial to reach out to certain stakeholders. Even if those groups cannot make a technical contribution to the task of risk assessment, their views are a crucial part of the knowledge needed

Even at home, Canada has been unable to properly address asbestos-related health risks because of this conflict of interests. There was no asbestos dust standard in place in Quebec until 1978 and, even since then, the occupational exposure limit for chrysotile asbestos has remained ten times higher than the generally accepted international standard [Brophy et al., 2007].

The Israeli-Palestinian conflict

- Dealing with complex and intractable conflicts involving material interests as well as values and ideologies.

The conflict between Jewish and Palestinian nationalisms – the desire of both peoples to establish an independent nation-state on the same territory, to which both groups have long-standing claims – is at the root of this continuing conflict, one of the world's major sources of geopolitical instability and risk. However, this conflict is not only over material interests such as land, water and security, but also involves questions of ideology, identity and values. Such issues are evident when one considers how central and sensitive the question of the "ownership" of Jerusalem and the stewardship of key religious sites for both Jews and Muslims has been throughout the conflict. What's more, the influence of religious (Zionist and Islamist) ideologies on both sides has affected the attitudes, perceptions and fears of the stakeholders, thus complicating the task of reconciliation. Decades of acrimony and violence have built up a legacy of mistrust, fear and bitterness [Tessler, 1994; Beinin and Stein, 2006].

Over the years, many efforts have been made to try to resolve the competing claims and halt the sporadic violence and war that have repeatedly broken out between the two parties. After UN Resolution 181 failed disastrously by trying to impose a rational, yet perhaps simplistic, solution, later efforts focussed on mediation and promoting negotiation [UN, 2008]. These efforts included bilateral and multilateral negotiations under the auspices of international organisations (the UN), great world powers (US, Soviet Union) or a combination of both (the Quartet, which involves the US, the EU, the UN and Russia, in 2002). Some negotiations between Israel and neighbouring Arab states have been successful (Israel signed peace treaties with Egypt in 1979 and Jordan in 1994) [IMFA, 2007], but the conflicts of interest, negative past experiences and strong ideologies dividing the Israelis and Palestinians have thus far prevented any lasting peace. Many observers regard this conflict as one of the most intractable in the world today.

B13 Acting in the face of the unexpected

Insufficient flexibility in the face of unexpected risk situations

As in the failure to imagine surprises (A10), risk managers may be unable to *act* in the face of the unexpected. This risk governance deficit occurs when people and organisations are not prepared or able to swiftly adjust their risk management strategies to respond to new emerging risks, rapid changes in the risk landscape, or unexpected crises and emergency situations. Organisational capacity that is well-suited to dealing with today's risks may prove inadequate tomorrow when new threats, abrupt change and paradigm shifts fundamentally transform the context within which risks must be managed. Here, the deficit may arise because risk managers delay the change from routine to crisis management or because they have not previously envisaged and planned for the need to make changes. Many crises could have been managed more effectively if risk managers had planned for the crisis or responded to it more promptly.

Acting in the face of the unexpected requires creativity, especially the encouragement of unconventional

thinking and innovation, plus the capacity to make decisions in situations of aleatory uncertainty[6]. Processes are needed that generate insights and ideas situated on the margins of current thinking and that challenge conventional wisdom to imagine possible futures. Such techniques (e.g., scenario planning or expert Delphi) are useful as part of the risk manager's portfolio in order to be better prepared for future surprises and emergencies, as for example with contingency planning for a global influenza pandemic [WHO, 2005].

When unexpected events occur, professionals who deviate from mainstream opinion and advocate outsider positions are often denounced as troublemakers and ignored, or even demoted instead of being rewarded. Without strong support and backing from the senior leadership of an organisation, imaginative professionals will not be inclined to think laterally or express original thoughts. The result is that people and organisations can confine their attention only to a standard list of agreed risks, which creates vulnerability to unexpected or emerging risks.

Given that there will always be more unconventional opinions than there are future risks, it is also important for risk managers not to be too readily diverted from mainstream thinking by poorly supported lateral thinking. Thus, openness to new ideas must be accompanied by rigorous scrutiny of those ideas. It is also important to realise that we will never be able to predict and be prepared for all future outcomes, no matter how thorough and able our foresight, and, in such circumstances, readiness and ability to change routine procedures become more important.

Where there is a need to deal with the unexpected, including sudden change associated with emerging risks, decision-makers may neglect, or refuse to acknowledge, such risks. Denial may be especially problematic if economic, political or environmental systems are about to change or are already changing, and thus new approaches are needed.

Risk management failures can also arise when decision-makers have neglected to build redundancies and resilience into systems that might be exposed to unknown or uncertain threats, or when they are unable to draw on slack resources or reassign resources from elsewhere. Such actions could reduce system vulnerabilities and allow for a quicker recovery after a hazardous event has occurred [IRGC, 2005]. Building redundancy on the one hand and being able to adapt quickly on the other are thus complementary components of a risk management strategy which, by increasing resilience, can be a valid approach to responding to the unexpected.

Hurricane Katrina

- Failure to respond adequately owing to the huge and unexpected scale of the destruction.

Although Hurricane Katrina itself was not an unexpected event – meteorologists had been closely tracking the storm's evolution for a week and New Orleans is on a hurricane-prone part of the Gulf coast – the extent of devastation caused was much greater than anyone had imagined possible. Eighty percent of New Orleans was flooded, over 1,800 people died, oil platforms were damaged, oil refineries had to be closed and over 1 million hectares of forest land were destroyed. Human, economic and environmental costs were extremely high, making Katrina the costliest hurricane in US history.

Faced with the extent of this devastation, however, federal responders seemed unable to make the switch to crisis mode, instead treating Katrina as if it were a "normal" hurricane. People in charge assessed the problem they were facing by referring to events from the past, underestimating its scope and scale, and they failed to shift their frames of reference until it was too late.

For example, many Department of Homeland Security (DHS) officials saw the designation of "Incident of National

6) Aleatory uncertainty occurs because of natural, unpredictable variation in a system and cannot be decreased through scientific research. Risk analysts distinguish between aleatory and epistemic uncertainty, the latter arising owing to a lack of knowledge about system behaviour. Epistemic uncertainty can thus be reduced by more scientific research [IRGC, 2005: 28].

Signifcance", which would have expanded the federal response, as reserved for terrorist attacks. This delayed the declaration of Katrina as such an incident until a day after landfall, when much of New Orleans was already fooded, slowing down emergency and rescue efforts [Moynihan, 2008].

The Millennium Bug

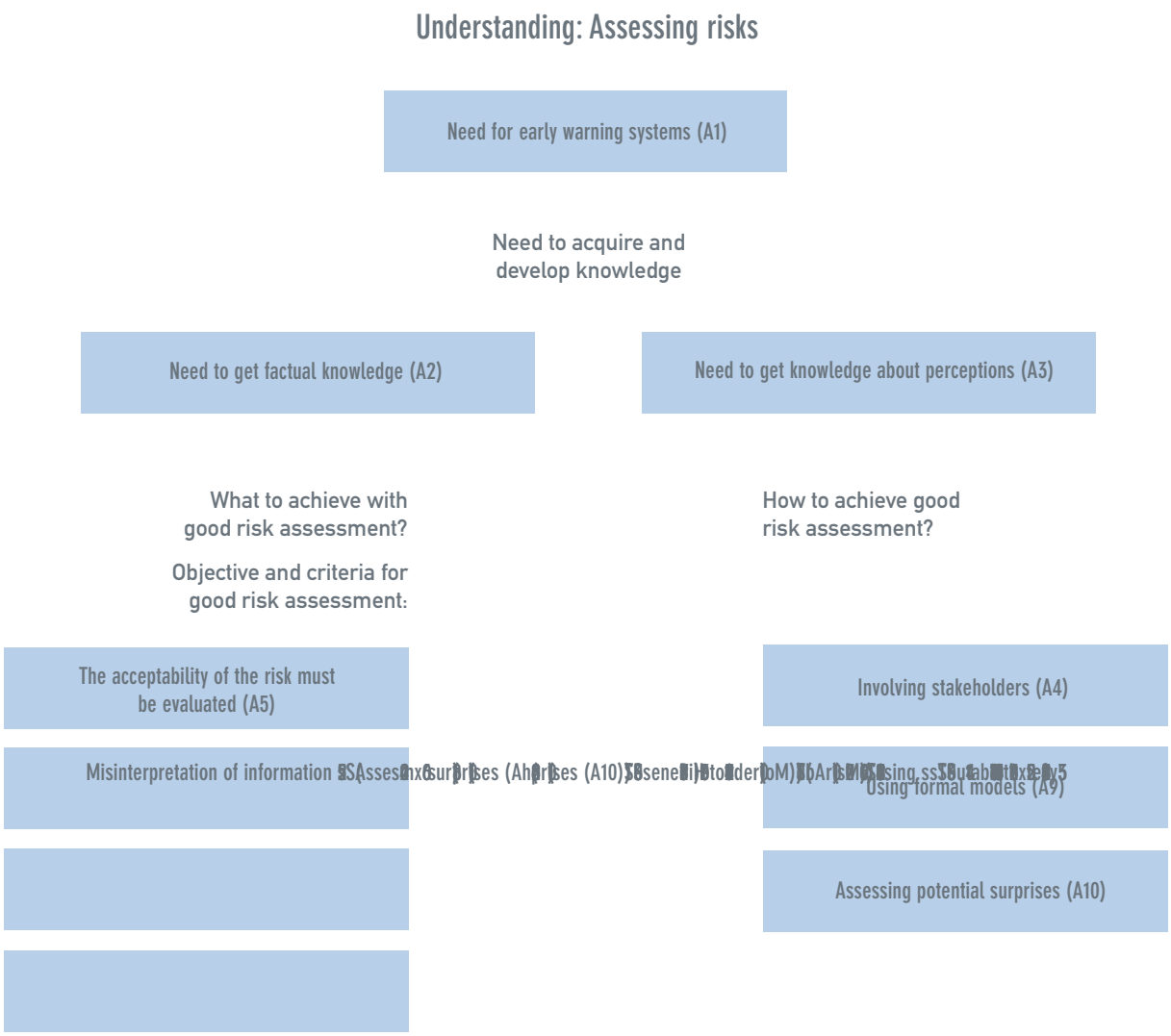
- Success (building redundancy and resilience) or overblown fear?

The "Millennium Bug" (Y2K or Year 2000 bug) was the possible failure of computers to deal with date-related data between December 31, 1999 and January 1, 2000. Many risk analysts predicted that the consequences could be huge, but potential damages were impossible to assess.

Companies and organisations around the world checked and upgraded their computer systems. The US government is one of those which took the matter extremely seriously, passing the Year 2000 Information and Readiness Disclosure Act, whereby it worked with the private sector to ensure readiness and promoted plans with internal continuity in the event of information technology related failures. However, when the year 2000 came, no country experienced any problems regarded as worth reporting. So had the steps taken to reduce risk worked? Or was the problem imaginary to begin with (over-estimation and over-reaction leading to over-zealous risk management)?

Actions taken to remedy possible Y2K problems did have some benefts. With many businesses installing computer backup systems for critical fles, preparation for Y2K had a signifcant effect on the computer industry and on contingency planning, forcing senior management to consider how they would operate their businesses in the event of a business disruption [Cumming, 2002]. It has also been suggested that on September 11, 2001, the New York infrastructure (including subways, phone services and fnancial and banking systems) was able to continue operation because of the decentralisation of infrastructures, the creation of multiple sites for backup data and contingency plans established in 1999.

Preventative management through redundancy and resilience building can be an effective risk mitigation strategy for risks with aleatory uncertainty.

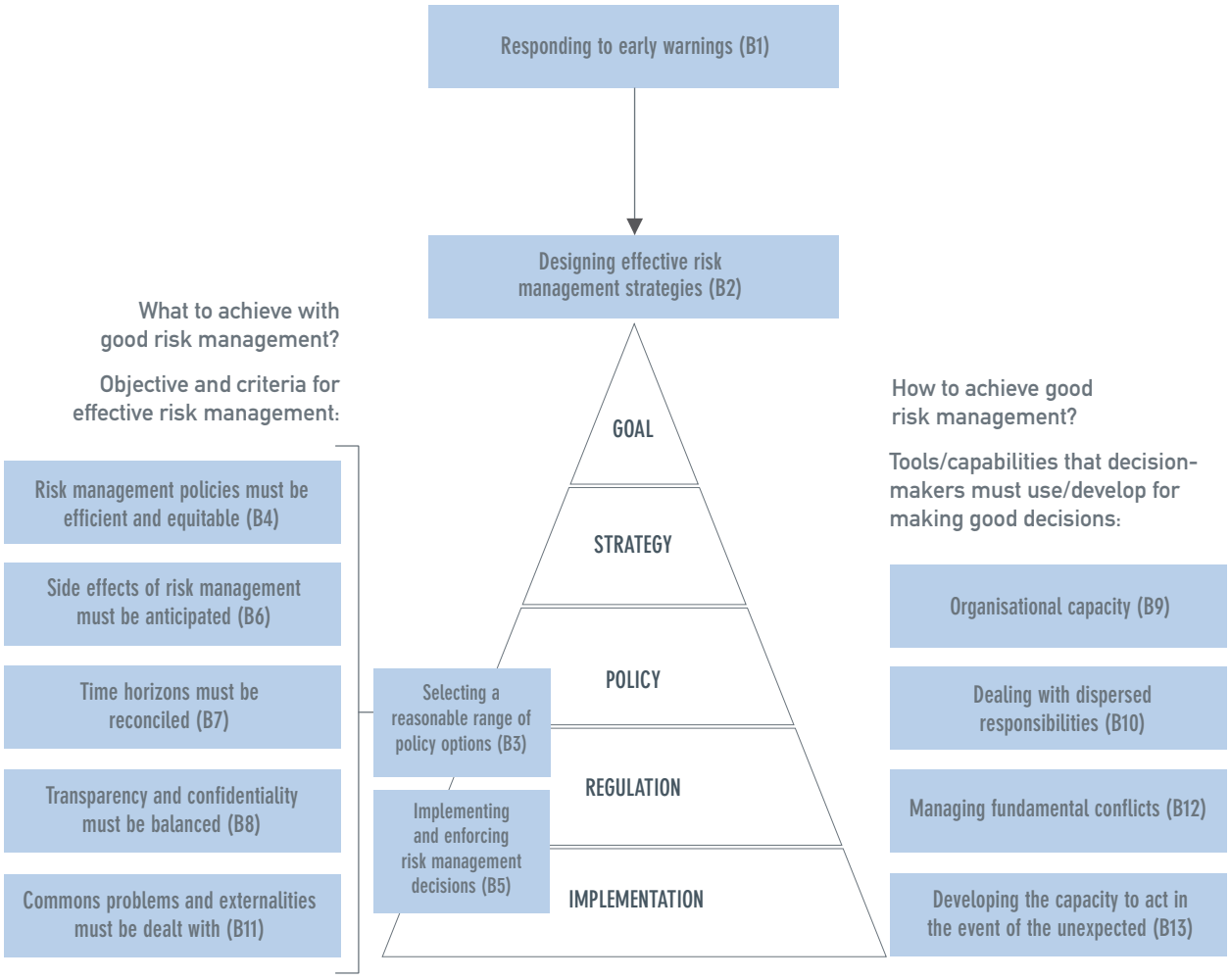

Understanding: Assessing risks
Need for early warning systems (A1)
Need to acquire and develop knowledge
Need to get factual knowledge (A2)
Need to get knowledge about perceptions (A3)
What to achieve with good risk assessment?
Objective and criteria for good risk assessment:
How to achieve good risk assessment?
The acceptability of the risk must be evaluated (A5)
Involving stakeholders (A4)
Using formal models (A9)
Assessing potential surprises (A10)

With the two charts below, we propose an organisation of the deficits that decision-makers could use when they conduct an assessment of how their organisation handles risk governance.

Each chart identifies the deficits related to:

- establishing the basic elements of risk assessment and management
- criteria for evaluating the quality of the outcome: what objective must be achieved
- instruments and capacity that need to be developed: how to achieve the objective

Acting: Managing risks



Allocation of deficits to the left or right side of this chart may be subject to interpretation, but intends, here, to focus on the main characteristics of each deficit. B12 and B13 in particular could be considered to include elements of both objectives and criteria.

IRGC has identifed the 23 defcits described in this report as important because of their propensity to recur frequently and to have an impact on the effective governance of a wide range of risk types in many varying contexts and circumstances, with potential severe consequences. It is apparent that defcits are interrelated; that multiple defcits are often implicated in the governance of a single risk issue; that one defcit may occur in a variety of different ways; and, that prioritising them for certain types of risks or in certain sectors could be helpful.

IRGC chose deliberately not to prioritise the defcits. Doing so could inappropriately divert decision-makers' attention from some defcits perhaps perceived as less important than others but of higher importance to them. The list of 23 defcits may be used as a checklist to evaluate a risk governance process.

Diagnosis and remedy of defcits is not a one-time event, but rather an ongoing process of fnding problems and fxing them. The work done in the course of this project on risk governance defcits has highlighted the importance of the *interactive processes* between risk assessment and management, and between risk generators and those who are affected by risks.

One of the central elements of these interactions is the role given to the inclusion of *stakeholders*, and in particular the public, in the decision-making process. Stakeholders are central in assessing and evaluating the risk, as well as in accepting the decision and implementing it. Deciding which stakeholders to involve and how is often a very diffcult and delicate task.

Interactions between some stakeholders – industry, regulators and the public – also have the power to determine innovation outcomes, whether through encouragement or constraint. As highlighted in the introduction to this report, the inability to take full advantage of the *benefts* that innovation, whether technological or social, could bring to society is an important potential consequence of risk governance defcits.

However, sometimes discussion or negotiation between stakeholder parties reaches an impasse and

technological social

In conclusion, it is important to note that IRGC does not view the list of defcits presented in this report as being either exhaustive or fxed. There may be some degree of overlap between the defcits presented here and, as already noted, some are certainly interlinked. Nevertheless, IRGC hopes that the way in which the defcits have been described and categorised in the report can be useful to risk decision-makers in helping them to identify defcits that are relevant to their own organisations, and to refect upon how such defcits can be avoided so that trust is built into how the risks are dealt with and in who deals with them.

Further feedback from risk practitioners on the usefulness or relevance of this report is welcomed.

VI Overview

Cluster/sub-cluster	Deficit	Short description	Illustrations
A: Assessing and understanding risks			
Gathering and interpreting knowledge	A1: Early warning systems	Missing, ignoring or exaggerating early signals of risk	• The subprime crisis in the United States • Tsunami early warning system in South-East Asia
	A2: Factual knowledge about risks	The lack of adequate knowledge about a hazard, including the probabilities of various events and the associated economic, human health, environmental and societal consequences	• Radio-frequency electromagnetic fields • Replacing one gasoline additive with another (MTBE)
	A3: Perceptions of risk, including their determinants and consequences	The lack of adequate knowledge about values, beliefs and interests and therefore about how risks are perceived by stakeholders	• Genetically modified foods • Risk perceptions of nuclear power
Disputed or potentially biased or subjective knowledge	A4: Stakeholder involvement	Failure to adequately identify and involve relevant stakeholders in risk assessment, in order to improve information input and confer legitimacy on the process	• Large infrastructure projects (dams)
	A5: Evaluating the acceptability of the risk	Failure to consider variables that influence risk appetite and risk acceptance	• Radioactive waste disposal
	A6: Misrepresenting information about risk	The provision of biased, selective or incomplete information	• The tobacco industry and the risks of tobacco products • Disposal of the Brent Spar platform • BSE and beef supply in the United Kingdom
Knowledge related to systems and their complexity	A7: Understanding complex systems	A lack of appreciation or understanding of the potentially multiple dimensions of a risk and of how interconnected risk systems can entail complex and sometimes unforeseeable interactions	• The subprime crisis in the United States • Fisheries depletion (Barents Sea capelin)
	A8: Recognising fundamental or rapid changes in systems	Failure to re-assess in a timely manner fast and/or fundamental changes occurring in risk systems	• The HIV/AIDS epidemic • Potato blight and the Irish Potato Famine
	A9: The use of formal models	An over- or under-reliance on models and/or a failure to recognise that models are simplified approximations of reality and thus can be fallible	• Fisheries depletion (Newfoundland cod) • The subprime crisis in the United States
Knowledge and understanding are never complete or adequate	A10: Assessing potential surprises	Failure to overcome cognitive barriers to imagining events outside of accepted paradigms (“black swans”)	• 9/11 terrorist attacks

B: Managing risks		
The preparation and decision process for risk management strategies and policies	B2: Designing effective risk management strategies	Failure to design risk management strategies that adequately balance alternatives
	B3: Considering a reasonable range of risk management options	Failure to consider a reasonable range of risk management options (and their negative or positive consequences) in order to meet set objectives
	B4: Designing effcient and equitable risk management policies	Inappropriate risk management occurs when benefts and costs are not balanced in an effcient and equitable manner
	B6: Anticipating side effects of risk management	Failure to anticipate, monitor and react to the outcomes of a risk management decision in the case of negative side effects
	B7: Reconciling time horizons	An inability to reconcile the time frame of the risk with the time frames of decision-making and incentive schemes
	B8: Balancing transparency and confdentiality	Failure to balance two of the necessary requirements of decision-making: transparency, which can foster stakeholder trust; and confdentiality, which can protect security and maintain incentives for innovation
	B1: Responding to early warnings	Failure of managers to respond and take action when risk assessors have determined from early signals that a risk is emerging
Formulating responses, resolving conficts and deciding to act	B11: Dealing with commons problems and externalities	A lack of understanding of the complex nature of commons problems and consequently also of the specifc risk management tools required to address them
	B12: Managing conficts of interests, beliefs, values and ideologies	A confict may be negotiable or irreconcilable, and risk managers must have the capacity to distinguish between the two
	B13: Acting in the face of the unexpected	Insuffcient fexibility in the face of unexpected risk situations
Organisational capacities for responding and monitoring	B5: Implementing and enforcing risk management decisions	Failure to muster the necessary will and resources to implement risk management policies and decisions
	B9: Organisational capacity	Failure to build or maintain an adequate organisational capacity to manage risk
	B10: Dealing with dispersed responsibilities	Failure of the multiple departments or organisations responsible for a risk's management an

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Annex: Case studies (Summaries)

EMF: Mobile phones and power lines

By Leeka Kheifets, John Swanson and Shaiela Kandel

Power-frequency electric and magnetic fields (EMFs) have been present in industrialised countries since public electricity supplies appeared in the late 19th century, while the increases in cellular communications and other technologies emitting radio-frequency EMFs have been particularly rapid over the last decade. For power-frequency EMFs, the conventional scientific view is that even if there is a risk, it would be unlikely to be of major significance for public health. For radio-frequency EMFs, more reliable studies need to be conducted, but most reviews to date are broadly reassuring and conclude that, based on current evidence, there is no great reason to be concerned about health risks. Nevertheless, the question of EMFs attracts considerable public concern, uncertainties surrounding the scientific evidence are not insignificant and there are those who contend that risks are being underestimated. These uncertainties have complicated the risk governance of power and radio-frequency EMFs, and several deficits are evident in the way that risks related to EMFs have been handled over time.

Overview of the risk issue

EMFs are physical fields produced by the interaction between the charges of electrically charged objects. EMFs have varying frequencies and intensities. High-frequency fields that carry energy sufficient to break bonds between molecules (such as X-rays and gamma rays) are called ionising radiation and are known to be carcinogenic to humans. Lower-frequency EMFs are non-ionising and include radio frequencies (e.g., radio, television, mobile phones) and power frequencies (e.g., electrical appliances, power lines). A great deal of research has been done on the biological effects of long-term exposure to radio- and power-frequency EMFs; however, the results are unclear and controversial.

Because power-frequency EMFs have been around longer, knowledge about their associated risks is more developed. In this case, there is some evidence (albeit weak) that exposure to elevated levels of power-frequency EMFs is implicated in childhood leukaemia. The World Health Organization (WHO) and the International Agency for Research on Cancer (IARC) thus classify extremely low-frequency EMFs as “possibly carcinogenic”. Concerns over health risks have led to delays in building power lines and to increased costs of power line installation (due to costs of EMF mitigation measures).

For radio-frequency EMFs, the epidemiological evidence of health effects is sparse and uninformative: studies of children and of many specific diseases are lacking, exposure assessment is still immature and the technology is constantly changing. Exposure assessment is thus still in its infancy and, while current evidence suggests no obvious adverse effects, knowledge gaps and long latency periods mean that adverse effects may yet be discovered and that the safety of radio-frequency EMFs cannot be assumed.

Both parts of the issue – power frequency and radio frequency – attract public concern. In risk governance terms; therefore, the principal issue concerning power-frequency EMFs is how to respond to weak and uncertain scientific evidence that nonetheless causes public concern. For radio-frequency EMFs, it is the combination of the rapid growth of new exposures over a relatively short time, little scientific evidence but large potential consequences, and significant public concern that may lead to risk governance deficits.

Risk-handling process

In the early period of power-frequency risk management, the main deficit can be seen in retrospect as a tendency by the mainstream, "establishment" scientific community to manage the issue purely on the basis of its assessment of the science, with limited regard for alternative scientific views (A2) or for the legitimacy of lay perspectives (A3), and, consequently, insufficient consideration of risk communication as a policy option (B3). To be fair, these deficits should be seen in the context of the times. The initial scientific evidence was, objectively, weak. It was not, perhaps, until the late 1990s that the evidence started to accumulate (although still amounting to only a "possible" risk), and around that time, the mainstream scientific community did change its stance so as to recognise this. In more recent years, the main issue has been selecting the appropriate policy (B2, B4), with a risk that alarmist or unbalanced presentations of trade-offs could skew the optimum outcome and encounter public opposition.

With radio-frequency EMFs, the fundamental vacuum in the scientific evidence, largely an inevitable consequence of the recent introduction of new or rapidly changing technologies, prompts a debate about early warnings (A1, B1). A clear distinction should be made between evidence of the absence of an effect and the absence of evidence of an effect – for radio-frequency EMFs, this distinction is sometimes intentionally or unintentionally obscured (A6). In risk governance terms, the major problem is how to decide upon what constitutes the "correct" course of action, given that this new technology cannot be expected to manifest any early warnings until years after it is introduced.

Both the power-frequency and radio-frequency EMF issues have exhibited two further common problems. One is that, even when decision-makers are favourable towards the inclusion of a wide variety of interests and groups in the risk governance process, there is uncertainty as to what weight to give small but vocal groups, or groups with largely local concerns (A4).

The other is that, almost inevitably, different groups have represented the science to their best advantage, sometimes to the point of distortion (A6). An example from one side would be the highlighting of a single, seemingly positive, experimental study, without considering the weight of evidence from the totality of relevant studies. Examples from the other side would be references to numerous negative studies when many of them may not be especially relevant to human health, may not have had the resolving power to detect an effect or may have relied on over-simplistic arguments (based on crude energy considerations) for the impossibility of any effects.

Likewise, in the area of policies rather than science, those resistant to the introduction of certain policy measures have sometimes tended to overstate the possible adverse consequences or side effects of policy implementation (B3); or, conversely, those advocating certain policy options may fail to recognise that these policies can have consequences (B6). To give examples, for power-frequency EMFs, where one major source is the high-voltage power line, there are a set of inter-related issues about land use and land values adjacent to such lines: the different economic interests of nearby residents versus those of society as a whole, the availability of land to meet broader societal objectives, etc. The consequences that any EMF mitigation measures could have for these wider issues must be considered. This may not be appreciated by the proponents but, equally, may be overstated by the opponents of such measures. Similar issues apply to, for example, cell-phone base stations and, in both cases, there are issues of equity (B4) between those experiencing the exposure and receiving some benefit, those experiencing the exposure and not receiving direct benefit, and society as a whole. Radio-frequency EMFs and, particularly, cellular communications have an undeniably enormous impact on societies. They have a downside (e.g., contributing to collisions if used when driving), but there is broad agreement that the overall effect is positive, through improved communication generally as well as specifics such as expediting help in medical emergencies. It would be hard to justify restricting those benefits, but there is dispute as to the extent to which various precautionary measures would in fact limit the use of, and benefit from, these technologies.

Once some jurisdictions have taken action, there is understandable pressure on others to take the same or further

action. No regulator or, even less, politician, wants to be seen to be lagging behind in public protection. This can lead to a “race to the bottom” where the measures taken can become disconnected from scientific reality. This is exacerbated when stricter limits are adopted in some countries but are not enforced (B5), and are then misrepresented in other countries as examples of superior protection. On the other hand, a long latency for cancer and other diseases coupled with the short-term horizon of decision-makers can lead to a systemic bias for taking no action (B7).

We conclude that risk management of EMFs has certainly not been perfect, but for power-frequency EMFs risk management has evolved and can be largely considered a success. Lessons from the power-frequency experience can benefit risk governance of radio-frequency EMFs and other emerging technologies.

The response to Hurricane Katrina

By Donald Moynihan

Hurricane Katrina made landfall on the coast of Louisiana on Monday August 27, 2005. It was the largest natural disaster in the United States (US) in living memory, affecting 92,000 square miles and destroying much of the city of New Orleans. Over 1,800 people died and tens of thousands were left homeless and without basic supplies. The destruction that resulted, although primarily caused by the hurricane itself, was also a result of the collapse of man-made levees that were supposed to protect the city of New Orleans. The direct costs of repairs and reconstruction plus the damage caused to the national economic infrastructure, including disruptions to the oil supply and to the export of grains, are estimated at approximately US$110 billion, making Katrina the costliest hurricane in the history of the US. Significant failures in risk governance, both in the preparation for and in the response to the hurricane, contributed to the high human and economic costs of Hurricane Katrina; however, in this case study, we concentrate mainly on the *response*. For this reason, most of the deficits described in this summary and the associated case study are deficits of risk management (cluster B).

Overview of the risk issue

The city of New Orleans, with a population of approximately 455,000 (in 2005, pre-Katrina), is the largest city in Louisiana and one of the oldest cities in the US. Situated in the Mississippi River Delta, much of the city is below sea level (average elevation is -0.5m) and therefore very susceptible to flooding.

Although Louisiana and Mississippi together account for only 2% of US gross domestic product, storm damage to that region of the Gulf coast has the potential to cause substantial economic harm for more than just the affected regions. This is because of the economic importance of the port of New Orleans (one of the largest and busiest ports in the country) and of the energy infrastructure in the Gulf region, which produces 6.5% of domestic crude oil consumption and 16% of natural gas consumption [CRS, 2005].

This area of the US coast has always been at risk from hurricanes; however, coastal erosion in Louisiana over the course of the 20th century has made the New Orleans area even more susceptible to storm surges. Since the Flood Control Act of 1965, flood walls and man-made levees have been built to try to protect the city and surrounding region.

Risk-handling process

The consequences of a major hurricane had long been anticipated for New Orleans. Indeed, the threat of hurricane disaster even had its own name – “the New Orleans scenario” – and in the years prior to Katrina, Federal Emergency Management Agency (FEMA) staff ranked the New Orleans scenario as being one of the most critical potential disasters facing the US.

a) Failure to respond to the threat

Despite the risks and the gravity of potential consequences, however, the level of preparation and the funding devoted to hurricane protection and response in New Orleans prior to Katrina was far from adequate. FEMA had a hard time finding the money to run simulations and devise plans for responding to a hurricane disaster, while the design and construction of the New Orleans system for hurricane protection[7] was flawed, safety having been put second to cost reduction (B2, B1) [ILIT, 2006].

In the days leading up to Katrina's landfall in New Orleans, the National Hurricane Center and National Weather Service issued multiple forecasts and hurricane watches. By Friday August 24, the tropical depression that would become Hurricane Katrina had become serious enough that the governors of Mississippi and Louisiana declared states of emergency. National Weather Service forecasts changed predictions, first saying that the hurricane was heading to New Orleans at 11 a.m. on Friday. By 4 p.m. the storm was predicted to hit the Mississippi coast. By 4 a.m. on Saturday New Orleans was again expected to be hit. On that day, voluntary evacuations began in Louisiana, President Bush declared a state of emergency and FEMA and state emergency responders began 24-hour operations. By 7 p.m., the National Weather Service warned that levees could be topped in New Orleans, causing catastrophic flooding. Still, no mandatory evacuation was ordered for New Orleans. This did not come until 9:30 a.m. on Sunday (B1). Katrina made landfall at 6:10 a.m. on Monday.

At the federal level, too, responders lacked urgency and treated Katrina as if it were a normal storm. It seemed that they were taken by surprise because no one had imagined that the impact of a hurricane could be so extreme (A10). Reports of levee breaches in New Orleans on the day of landfall were treated with scepticism by the Department of Homeland Security (of which FEMA is a part), which did not use resources on the ground in New Orleans to verify the extent of the flooding. This failure to understand the scope and scale of the disaster and the numerous complex systems affected by it (A7) contributed to the delay in staging an appropriate response.

b) Failure to adequately respond to the damage caused

But even as the needs created by Katrina became clear, the sheer scope of the disaster challenged an all-out response effort. A catastrophe so large requires more of everything, especially resources and responders, and the size of this disaster made even extraordinary efforts insufficient. Again and again, for evacuation, medical response, search and rescue, and temporary shelters, government efforts were unprecedented. The evacuation of New Orleans was the largest evacuation of a US city in such a short period. Efforts to shelter the homeless were also extraordinary. The Department of Defense produced the largest domestic military deployment since the civil war, and the National Guard deployment of 50,000 troops was the largest in US history, but these efforts fell short of needs, often dramatically. A catastrophe of this scale not having been expected, there was simply not enough capacity to respond (B13).

The Katrina network was so large that there was a failure to fully comprehend all of the actors actually involved (partly because of a large voluntary component), the skills they offered and how to use these capacities [House Report, 2006: 302]. The way that responsibilities were dispersed between federal, state and local responders further complicated response efforts in this case, because the normal "pull" approach used in US crisis response (where a gradual expansion of government involvement occurs as local and then state responders need help) was inappropriate for the situation. Despite local and state capacity being immediately overwhelmed, federal responders waited for requests for aid instead of taking a more aggressive "push" approach. New policies outlined in the National Response Plan that aimed to formalise the distribution of responsibilities and lay out rules for coordination instead led to confusion [Senate Report, 2006]. Such confusion complicated efforts to foster a central command in the field, where three major federal operational commands ended up competing in an uncoordinated manner: the Joint Field Office and Federal Coordinating Officer, the Principal Federal Official, and the Joint Task Force Katrina (B10).

7) The Lake Pontchartrain and Vicinity, Louisiana Hurricane Protection Project in the Flood Control Act of 1965 was an incomplete project already more than 40 years in the making when Katrina hit [GAO, 2005].

Following the crisis, both the Senate and House reports investigating the inadequate response by federal agencies identified serious problems related to organisational capacity (B9). The post-9/11 shift towards the terrorism threat had led to a neglect of natural disasters and resulted in FEMA growing critically weak as it was stripped of resources, responsibilities and direct White House access. Understaffed, and with weak leadership and redu ed ɔt û in FEMA

are effectively an open-access resource, meaning that they can be caught by anyone. In such a situation, each individual user tries to extract as much of the resource as possible in order to obtain the maximum personal benefit before the resource is exhausted. With no incentive to conserve the resource, the natural outcome is overfishing of fish stocks and eventual collapse of fisheries. To overcome this problem, a governance regime must find a way to restrict access to the resource and to create incentives for users of the resource to conserve it and invest in it rather than overexploiting it [Ostrom et al., 1999: 279]. Governance regimes must be tailored to the specific circumstances of the fishery in question and must overcome numerous obstacles such as: coordination of large numbers of stakeholders; difficulties in accurately measuring fish stocks; the migratory nature of fish stocks; different impacts from different fishing technologies; evaluating the impacts of exogenous factors on fish populations; or coping with the large size and scale of the resource system.

Regulation at the international level to try to solve the commons problem of fisheries has been evolving for at least the past 50 years (since the first UN Conference on the Law of the Sea in 1956). Regional and national efforts, too, provide reasons to be optimistic about the future, as new initiatives adopt ecosystem-based approaches to fisheries management and learn from the successes and failures of the past. Below, we review some of these past successes and failures and point out where risk governance deficits have been most evident in these examples of fisheries governance.

Risk-handling process

Fisheries management is particularly susceptible to knowledge-based governance deficits (cluster A). First of all, it involves complex systems which may not be well understood (A7). Scientific information in this domain often comes with a significant degree of associated uncertainty because of the complexity of marine ecosystems and problems defining scope and scale (for example, should a fish be regulated on a species basis? A population basis? Or an ecosystem basis?). Scientific knowledge about the life cycles of many fish species is limited, as is knowledge of how the oceans and marine ecosystems respond to pressures, and thus also how fish stocks will react to pressures, both human and environmental (A2) [Richards and Maguire, 1998]. In the case of the Atlanto-Scandian herring fishery in the 1950s and 1960s, lack of this kind of knowledge led to overly optimistic assumptions about how quickly depleted fish stocks could be rebuilt (the origin of this idea being that a single herring can produce hundreds of thousands of eggs). Thus, when sudden improvements in fishing technologies significantly increased the size of herring catches – mechanical winches made it possible to use bigger boats and sonar made it easier to locate shoals of fish – fishery managers did not grasp how fast and fundamental a change this constituted for the overall risk system (A8). No new regulations were introduced to compensate for faster extraction rates, with the result that the fishery collapsed in the late 1960s.

Indeed, there is even a degree of uncertainty involved in measuring and assessing existing fish stocks [Pattersen et al., 2001; Reeves and Pastoors, 2007]. For example, errors in the calculation of fish stocks in the Northern cod fishery (off eastern Canada) between the late 1960s and the late 1980s played a key role in the eventual collapse of what had once been considered one of the greatest fisheries in the world. In this case, the government had been employing mathematical models to set total allowable catches. However, while the model was a convenient tool for policymakers, it also had several design faws which caused it to overestimate cod populations by as much as 100%. Over-reliance on the results of this model led to quotas being set too high and, eventually, to the collapse and closure of the fishery in 1992 (A9). The cod stock has still not recovered sufficiently to allow the fishery to reopen.

Of course, having access to reliable knowledge about fish stocks is not sufficient in itself for good governance, since the knowledge that goes into risk assessment must be complemented, when necessary, by action taken during the risk management phase (cluster B). In the case of the North Sea herring fishery in the 1960s, managers were aware of early warning signs that fish stocks were unhealthily low (rapid declines in spawning stock biomass and catches composed of 80% juvenile fish had been consistently observed). Unfortunately, a failure to respond

to these early warnings (B1) led to the severe collapse of the fshery in 1975-76 and its closure in 1978. However, in this case, a lesson was learned from this previous failure, as when the fshery was fnally reopened (after 19 years) efforts were made to improve the management of fsh stocks [CEFAS, 1999]. In 1995, when early warning signs once again showed that fsh stocks were becoming dangerously low, quick and drastic action was taken to avoid another collapse. By 2003, the stock had recovered without requiring even temporary closures of the fshery [Simmonds, 2007][9].

The fact that fsheries are common pool resources also means that their management is prone to risk governance defcits related to strategies for dealing with commons problems and externalities (B11). In this case it is not that *no* strategy is determined, but rather that the strategy has many imperfections that are diffcult to resolve because fsh stocks often traverse the jurisdictions of multiple states or international waters. Responsibilities for managing fsh stocks are thus also dispersed, not always in a clear manner, between many different actors at both international and national levels (B10). This sometimes makes the implementation and enforcement of risk management policies more diffcult, as has been observed, for example, in the Mediterranean, where bluefn tuna stocks are fshed by at least 11 different coastal states. Regional management organisations, such as the EU or the International Commission for the Conservation of Atlantic Tuna, have thus far been unable to coordinate control and enforcement activities at the level required to combat the currently very high levels of overfshing and make sure that all of these states respect their tuna fshing quotas. As a result, the EU recently launched a Joint Deployment Plan (in March 2008) in an effort to step up enforcement efforts [CFCA, 2009].

Risk governance of genetically modified crops in Europe

By Joyce Tait

The development of genetically modifed (GM) crops and the global disparities that exist in the way they are regulated provide a good example of how defcits in the risk governance process can lead to negative consequences such as: opportunities and jobs lost, companies and countries disadvantaged, and regulatory time and resources wasted. From the perspective of industry and risk regulators, the European regulatory system for GM crops is seen as a failure of evidence-based risk governance – it is the most onerous regulatory system in existence for a commercially-traded product, despite a lack of evidence of health or environment-related risks. The European regulations are seen by some as an attempt to erect trade barriers against commodity crops produced using seed developed largely by American companies. Others see the current situation as a triumph of “David and Goliath” proportions where, since the mid-1990s, environmental, consumer and third world advocacy groups have increasingly dominated European policymaking on chemicals and pesticides as well as GM crops. Many farmers in developed and developing countries would like to grow GM crops but are worried about their ability to sell the resulting produce to European markets.

Overview of the risk issue

GM crops are created through genetic engineering to express desirable traits, such as pesticide or herbicide resistance or increased quantities of vitamins or amino acids. This is done by identifying and isolating a gene that governs the desired trait in another organism, then inserting this gene into the genome of the crop in question. For example, the US company Monsanto markets GM “Roundup Ready” soybean seeds, which have been made herbicide resistant by inserting a herbicide resistance gene from a bacterium.

When GM crops were being developed in the 1980s, the risks for human health or the environment were uncertain and the development of the technology was accompanied by major investments in risk-related research. Potential risks from GM crops and foods included: creation or transfer of allergens, development of antibiotic resistance

9) An important reason for the success was the support from the fshing industry. This support was partly due to the memory of the earlier collapse, but perhaps more importantly, the number of fshing vessels and companies involved in the fshery is small, and the feet has lately been well enough capitalized to benefit from long-term planning..

in micro-organisms, cross-breeding between GM crops and wild plants or other crops (including the potential to produce herbicide resistant weeds), evolution of pesticide-resistant insects, cross-contamination of non-GM crops or unexpected effects on biodiversity. Some of these risks may be inherently low, others may be minimised with good regulation or through technological options to reduce risks. There are also economic and social risks, for example from the monopolisation of world food markets by multinational companies or, in the case of third world farmers, either their dependence on expensive GM seeds or, alternatively, their inability to get access to GM seeds which could transform their farming systems.

GM crops can also offer substantial potential benefits such as: higher yields, greater drought tolerance and more efficient use of water, decreased use of pesticides (leading to reduced health and environmental risks), improved nutritional content and better storage life.

Risk-handling process

Knowledge about physical facts (A2) was initially a major issue in the risk governance of GM crops. There was little concrete evidence of either hazards or safety, but governments had to decide what was the appropriate approach to regulation. Given the scientific uncertainty about the risks of GM crops, the EU acted in a precautionary manner, building a new regulatory system to examine each crop on a case-by-case basis – a "process-based" approach. The US, by contrast, adopted a "product-based" approach using existing regulations for pesticides, food and feed [Tait and Levidow, 1992]. Companies developing GM crops in Europe initially collaborated willingly with the EU approach, partly because they saw it as a means of reassuring the public and partly because they expected the regulatory system to become less precautionary as more information about GM crop safety became available. However, increasing evidence of the safety of GM crops had little impact on the evolution of EU regulatory systems, which became more onerous over time (A2). Public opposition led to a *de facto* moratorium on GM crop development in the EU between 1998 and 2004, and the revision of the regulatory regime in 2003 (Regulations EC 1829/2003 and 1830/2003) actually led to a *more* precautionary set of rules, rather than the expected reduction in the degree of precaution. Basing the European regulatory system more on political lobbying and less on evidence of risk in the conventional sense has disadvantaged European companies developing GM crops and discouraged innovation (B2).

The actions of agrochemical companies developing GM crops provide several examples of risk governance deficits. In the early stages of development, they paid too little attention to the values, interests and perceptions of potential consumers of their product (A3) [Chataway and Tait, 1993]. They were aware of the potential of GM crops to arouse public concern about health and environmental risks. They were also informed in the late 1980s that emphasising the ability of GM crops to reduce pesticide use could influence the public debate in their favour. However, companies were in the ambiguous position of knowing that GM crops would undermine their insecticide and fungicide product ranges, and knowing also that failure to develop GM crops would undermine their competitive position in the long term.

Companies did consult with some stakeholders in NGOs, but there was a lack of broad public engagement (A4) and they optimistically expected any opposition to be short-lived. Their actions in buying up seed companies (as a route to market for their GM product) and proposing to develop genetic-use restriction technologies (GURTs) fuelled growing public opposition. (GURTs prevent GM crops from developing viable seed or cross-breeding with other plants and competing with non-GM species in the wild, but the technology was also interpreted as allowing companies to protect their investments by preventing farmers from saving GM seed to produce crops the following season). The values of some sectors of society were against large corporations controlling the world's food production systems and taking actions that were claimed to disadvantage small farmers in developing countries. Companies and anti-GM advocacy groups contributed to this failure of risk governance in that, in public debates on the risks of GM crops, both sides misrepresented the available knowledge (A6) and advocacy groups were more effective than industry in influencing policy processes.

More effective and earlier *public* engagement by companies and policymakers might have been able to dilute the influence of the more strident anti-GM advocacy groups, resulting in a more tractable outcome. However, many anti-GM advocates were ideologically motivated [Tait, 2001] and were unlikely to be influenced by evidence-based argument, so that an amicable resolution to the debate over GM crop regulation was unlikely. Regulators had the opportunity to decide whether such ideologically-motivated opposition should dominate decision-making for society as a whole and they chose to respond to prevailing European political pressures (B12). The precautionary regulatory regime in the EU, in comparison to that of the US, is less evidence-based and more driven by political and advocacy group influences than by formal approaches to risk governance. The outcome is inefficient (B4), providing an example of using scarce resources for unimportant risks and of regulation based on inappropriate analyses of costs, benefits, and other social and environmental impacts.

Although the companies developing GM crops could have acted differently and perhaps improved the risk governance process, given their internal and external decision environments and the ideological opposition they were facing, the industry did not hold the key to making a meaningful difference. Policymakers and regulators could have changed the course of the GM crop experience in Europe but, in the light of the political constraints they were facing, it is unrealistic to have expected them to take a different approach. However, the “lessons learned” in this case are not only of historical interest. The shadow of this GM crop experience, in Europe and in many other parts of the world, hangs over future scientific developments in food production and in many other areas. New regulatory and risk governance approaches need to be better adapted to the opportunities presented by 21st-century science, and to be robust, flexible and democratic in the face of current societal pressures while continuing to ensure safety for people and the environment.

The Bovine Spongiform Encephalopathy (BSE) epidemic in the UK

By Belinda Cleeland

The emergence of Bovine Spongiform Encephalopathy (BSE) in the UK and the early handling of the epidemic in British cattle in the late 1980s-early 1990s, especially in regard to the risks posed by BSE to humans, is an example of inadequate risk governance. During the worst stages of the epidemic, between 1988 and 2001, nearly 180,000 cattle were infected in the UK and 4.4 million were slaughtered as a precaution. As of September 2009, 165 people had died in Britain from new variant Creutzfeldt-Jacob disease (vCJD), the human form of BSE. Overall, governmental measures taken to try to halt the epidemic cost approximately 4.2 billion pounds, plus 25 million pounds for the inquiry that followed and 1.15 billion in economic losses for the affected industries. Although the UK epidemic is now over, the problem of BSE has not disappeared and many countries now have BSE legislation and risk management measures in place.

Overview of the risk issue

BSE, commonly known as mad cow disease, is a transmissible, neurodegenerative disease affecting cattle. The disease has a long incubation period ranging from 30 months to eight years, with the infectious agent thought to be a specific type of misfolded protein, called a prion. These malformed prions cause other native prion proteins in the brain to misfold and aggregate, leading to a spongy degeneration of the brain and spinal cord. Transmission between cattle occurs via the consumption of contaminated meat and bonemeal in cattle feed, and BSE is fatal, with no known cure or treatment. It is now believed that BSE may be transmitted to humans who consume infected beef or come into contact with other products derived from the nervous tissues of infected cattle [WHO, 2002].

At the time of the outbreak, the novelty of the disease meant that there was no knowledge about its pathology, and so decisions had to be made on the basis of guesswork and analogy with scrapie, a well-studied spongiform

encephalopathy of sheep, which is known to be non-transmissible to other species [Dressel, 2000]. It was thus not expected that this disease would prove zoonotic. There was also no diagnostic test to identify infected animals that had not yet shown clinical signs of the disease, which made removing infected cattle from the food chain next to impossible, short of slaughtering the entire British herd.

While BSE was first identified in the UK, it quickly spread to at least 28 other countries in Europe, Asia, the Middle East and North America. Half of these countries have identified only a handful of cases; however, many Western European countries have reported hundreds of cases (Portugal, Ireland and France were worst affected), with the number of cases in the UK nearing 200,000 [OIE, 2007]. Apart from the obvious impact on animal and human health, BSE has also had a significant impact on consumer confidence in the meat industry and its worldwide trade; government regulatory practices; animal feed manufacturing processes; and, at least in the UK, government reputation and public trust.

Risk-handling process[10]

BSE was first diagnosed by the UK State Veterinary Service (SVS) in late 1986, although given the disease's long incubation period it is thought that cattle in the UK were probably first infected by BSE in the 1970s. An embargo within the SVS on making information about the disease public impeded the early gathering of data on the spread of BSE until at least mid-1987 (B8) – the BSE Inquiry later stated that this embargo should not have occurred.

By the end of 1987, the UK Central Veterinary Laboratory had concluded that the cause of BSE could be the consumption by cows of meat and bonemeal made from animal carcasses and incorporated in animal feed. This conclusion was followed by a ban on incorporating ruminant protein in ruminant feed, which resulted in an 80% reduction in the rate of infection almost overnight. Nevertheless, more infections than expected continued to surface, which was later attributed to the government's crucial error in allowing the feed trade a five week grace period to clear existing feed stocks, thus allowing thousands more animals to be infected (B2, B5) [Ashraf, 2000]. Concerns about the possibility of transmission of this disease to humans led to the question of whether cattle showing signs of the disease should be slaughtered for human consumption. At this stage, the Department of Health (DH)[11] should have been asked to collaborate with the Ministry for Agriculture, Fisheries and Food (MAFF) in considering the implications of BSE for human health. However, this did not occur until March 1988 (B10).

Once contacted, the Chief Medical Officer at DH responded by setting up an expert working party (chaired by Sir Richard Southwood) to advise on the implications of BSE – this group advised in June 1988 that animals showing signs of BSE should be destroyed. As a result, a compulsory slaughter and compensation scheme was put in place in August 1988. However, MAFF had given the same advice to its minister prior to March 1988 – the lack of prompt and adequate collaboration between the two departments, MAFF and DH, delayed implementation of this crucial safety measure for months (B5, B10).

In February 1989, the Southwood Report, produced by the working party, was submitted to government and subsequently published. The report concluded that the risk of BSE transmission to humans was remote and that "it was most unlikely that BSE would have any implications for human health". In following years, this report was repeatedly cited as constituting a scientific appraisal that risks to humans from BSE were remote. In fact, the report did warn that if its assessment were incorrect, the implications would be very serious, but this warning was not given much attention (A6).

Failure to subject the entire report to an adequate review led to its shortcomings being completely overlooked, to factual information being distorted or ignored, and to the degree of certainty surrounding the risks of BSE to human health being overstated in the public domain (A6). Not only was the public repeatedly reassured that it was safe to

10) Unless otherwise noted, the following information is based upon facts contained in *The BSE Inquiry: The Report. The Inquiry into BSE and vCJD in the United Kingdom* [BSE Inquiry, 2000].

11) Note that, until late 1988 when the Transfer of Functions (Health and Social Security) Order 1988 came into force, the UK Department of Health was known as the Department of Health and Social Services. For the sake of simplicity, it is referred to only as DH in this document.

eat beef, it was given the impression that BSE was not transmissible to humans, which was not known for certain and turned out to be false. In reality, a lack of knowledge about the epidemiology and pathology of this novel disease made it impossible to confidently assess the risks to human health (A2). Even when, in 1989, MAFF and DH banned the use in human food of categories of cattle offal most likely to be infectious (SBO, specified bovine offal), this ban was presented to the public in terms that underplayed its importance as a public health measure (A6, B2).

Along with the ruminant feed ban, the human SBO ban was probably the most important policy regulation implemented during the outbreak. However, it was implemented too late and not sufficiently enforced, as shown by unannounced visits to abattoirs in 1995, which found that 48% were not complying with the SBO regulations (B5) [van Zwanenberg and Millstone, 2002]. When a cat was found to have contracted a previously unknown spongiform encephalopathy in 1990, the most likely explanation was that it had consumed infected pet food – this raised concerns that BSE was indeed transmissible and could "jump" species into humans. Nevertheless, at this point, no precautionary action was taken (B1). Transmissibility was eventually confirmed as the first cases of vCJD were diagnosed in the mid-1990s, and consumption of beef infected with BSE was deemed to be the cause [Dressel, 2000].

Overall, the handling of the BSE outbreak was far from optimal, especially in terms of risk management. The BSE Inquiry, opened in 1998, was set up to review the adequacy of the government's response to the disease and to draw lessons from what went right and what went wrong. The final report has over 20 pages devoted to "Lessons to be learned" from the experience.

Even since the UK epidemic died down in the early 2000s, BSE has persisted as a serious concern for the beef industry worldwide and for public and animal health. In the UK, cases of BSE continue to be diagnosed, albeit at the much reduced rate of fewer than four per week (cf. 850 per week in 1992) [DEFRA, 2008]. Other countries, too, continue to discover new BSE cases with one being diagnosed, for example, in Canada in November 2008. BSE-related legislation and risk management measures, such as feed bans and guidelines for culling, thus remain in place in many countries (for example in the EU, see [Europa, 2003]). The World Organisation for Animal Health has developed criteria to classify countries according to their risk status for BSE – negligible, controlled or undetermined – with each country's status being reviewed periodically [OIE, 2008]. Nonetheless, trade embargoes on beef continue to be a sensitive issue between some countries (notably between South Korea, the US and Canada in recent times). Indeed, the International Trade Commission released a report in 2008 estimating that trade restrictions resulting from BSE had cost the cattle industry US$11 billion from 2004 to 2007 [ITC, 2008].

The subprime crisis of 2007-08 in the United States

In the course of this report, the case of the US subprime crisis of 2007-08 has been used to illustrate several risk governance deficits. The following text is a brief overview of the context in which the crisis unfolded. It does not intend to represent a comprehensive analysis, but only to put in perspective the examples given in the report. IRGC acknowledges the fact that analyses, views and opinions of experts on financial risks may differ.

The subprime crisis is the most recent example of a financial crisis. Such crises occur with some regularity and, while many are limited to a localised market or sector, some are systemic and affect other markets and sectors (e.g., the Asian financial crisis in 1997). The subprime crisis has led to a global credit squeeze and severe recessions in many countries around the world. Many have called it the worst depression since the Great Depression of the 1930s.

Overview of the risk issue

A period of historically-low interest rates, starting in the early 2000s, enabled large numbers of US consumers to obtain mortgages for the first time. At the same time, more lenders decided to offer mortgages to higher risk borrowers. Circumstances combined to create a housing market bubble. Therefore, central to the origin of the subprime crisis in the US (here we do not comment on similar developments in e.g., the UK housing market) was the sale of mortgages to people who were too weak financially to have any realistic chance of repaying them. By their very nature, subprime mortgages were sold to people with a high risk profile. Borrowers ran the risk of defaulting and eviction from their repossessed home. Lenders, mostly banks, risked not being repaid. Loan guarantors risked having to pay out on the guarantees they issued to underwrite the lenders. However, few people believed there was risk as there was wide belief that home prices could not fall.

The systemic nature of the crisis derived from the pooling by financial institutions of the mortgages into mortgage-backed securities that were then sold on the open market. These were then repackaged in evermore complex financial products traded in international financial markets. This transferred the guarantors' and lenders' risks to other banks and financial institutions, including pension funds, provided financial institutions around the world with the opportunity to invest in the US housing market, and increased the money available in the US to support the purchase of homes. Mirroring the extent to which these derivative securities had been traded globally, the fall in US housing prices in 2007 precipitated both a global financial crisis in which banks in several countries collapsed and a credit squeeze that triggered a global recession.

Many other factors were influential. For example, incentive schemes (not least those influencing lenders and securities' traders) encouraged behaviours that further increased the risk; actions (and inaction) by regulators were inadequate to the need to manage the risk of a collapse in the system; and ratings agencies were unable to adequately assess the risk of the traded financial products.

Starting in late 2006, the US housing bubble began to deflate, as the building boom had led to a surplus of unsold houses, causing property prices to fall. This undermined the many mortgage-holders who relied on an increased valuation of their home when renegotiating the terms of their mortgage. Unable to refinance the mortgages, they instead began to default. In turn, this resulted in investor losses on the asset-backed securities markets. By mid-June 2007, two hedge funds owned by Bear Stearns were in financial trouble. The hedge funds tried to sell some of their subprime bonds, but there were no buyers. Investor confidence had fallen and there was no liquidity in the market. In the end, Bear Stearns had to inject USD 3.2bn to support the hedge funds.

More financial institutions started having problems and had to reassess the value of their investments. This led to a sequence of huge write-offs. Aside from a lot of subprime lenders declaring bankruptcy, it emerged that many large banks and hedge funds all over the world had subprime mortgage-backed securities as part of their portfolios, and therefore had also suffered large losses.

The repercussions of the subprime mortgage crisis have been serious and widespread. The world banking system lost a lot of its capital, trust in the system fell, and markets have become more risk averse. Many countries followed the US into recession. Many governments have intervened: the US government alone has provided over $1 trillion dollars of support to financial institutions, including the insurance giant American International Group.

Risk-handling process

Several risk governance deficits can be observed in this case.

It has been argued that the causes of the subprime crisis can be traced back at least as far as the Great Depression of the 1930s [Eichengreen, 2008]. Risk governance deficits have thus occurred over a long period of time and, in most cases, the negative consequences arising from these deficits have accumulated over many years and thus have not been immediately apparent.

An analysis of the causes of the Great Depression led to the passing of the Glass-Steagall Act in the US in 1933, bringing about banking reforms that separated investment and commercial banking and subjected the financial services industry to stricter regulation. As time passed, however, policy began to focus more on the advantages of liberalising financial markets, which led to deregulation and finally the repeal of the Glass-Steagall Act in 1999 [Eichengreen, 2008]. This destroyed the divide between commercial and investment banking, allowing commercial banks to compete with investment banks in some areas and pushing investment banks to create new products (such as mortgage-backed securities) and to undertake riskier activities.

These changes to regulation were not, in themselves, a bad thing; indeed, they made many people better off. Rather, the problem was that policymakers had failed to anticipate the speed and extent to which the existing regulatory regime became inadequate (as it was designed for a segmented industry) (B6), and, additionally, there was also a general failure to recognise just how fundamentally the system would change as a result of more deregulation (A8). As a result, updating the supervision and regulation of the financial sector was not adequately prioritised and financial innovation ran far ahead of financial regulation.

Equally influential was the strength of the perception amongst all of the principal actors involved (borrowers, lenders, loan guarantors, banks, financial institutions, etc) that house prices would rise inexorably (A3), meaning that evaluations of the acceptability of what were well-known risks were based on overly optimistic profit forecasts (A5). It was in this context that the level of subprime lending grew and became a problem.

Ineffective risk management was evident even at the lowest level – that of the agents selling the subprime mortgage loans – since these agents, who fell outside federal banking regulations, had no incentive to develop a proper risk management strategy (B2). The default risk involved in the loan did not affect their commission, and so they willingly sold mortgages to even the least credit-worthy clients. This was equally the case when banks were the originators of the loans, because the banks' ability to immediately remove the mortgage from their books by reselling it to an intermediary (which would then go on to securitise it) removed all incentive to focus on risk management and monitor their exposure [de la Dehesa, 2007].

Once sold, the process of securitisation led to these subprime mortgages being pooled with thousands of other loans and broken down into financial products such as collateralised debt obligations, which could then be sold to investors. These products were so complex that it was difficult, or even impossible, for investors to fully understand the real risks of the securities they were buying (A7). Instead, investors were guided by the ratings agencies. However, not only were the ratings agencies also faced with increasing complexity in the information provided to them by originators of the mortgage loans, but they also had an unresolved conflict of interest (B12) – they were paid by the issuer of the financial product, not the buyer. Therefore, it was in their interests to give triple A ratings.

Apart from the opacity of the financial products themselves, they were sold over the counter and were not traded or quoted in organised markets, adding to the lack of transparency in the securitisation process (B8).

Amidst this opacity and complexity financial models were seen as being able to help convince investors and lenders that their actions were 'safe'. However, an over-reliance on mathematical models (A9) led many institutions to miscalculate risk, since such models, "as complex as they have become, are still too simple to capture the full array of governing variables that drive global economic reality" [Alan Greenspan, cited in Shiller, 2008: 42]. The novelty of various financial products and loan schemes made modelling difficult (due to a lack of historical data) and meant that models had never been 'tested' by the experience of a recession or a slump in housing values. Market conditions did not match those experienced historically, and so the predictive power of models was weak – but most stakeholders failed to recognise this [Zandi, 2009: 107-110].

On the whole, it seemed that market participants and regulators all failed to see the looming crisis. Nevertheless,

there were some observers who voiced concerns about abusive behaviour on the subprime mortgage markets; simplistic risk models; the US housing ‘bubble’; and inadequate regulation long inade concS א ו

Glossary

Ambiguity: Giving rise to several meaningful and legitimate interpretations of accepted risk assessment results. Ambiguity can be interpretive (where different interpretations of an identical assessment result are possible) or normative (where different concepts of criteria or yardsticks that help to determine what can be regarded as tolerable can be used) [IRGC, 2005].

Complexity: Refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects [IRGC, 2005].

Efficiency: The ratio of the effective or useful output to the total input in any system.

Emerging risk: A new risk, or a familiar risk in a new or unfamiliar context (re-emerging). These risks may also be changing (in nature) rapidly.

Externalities: Externalities are implicated in commons problems and occur when an economic activity incurs external costs (negative externalities) or external benefits (positive externalities) to stakeholders who did not directly participate in the activity. For example, the economic activity of factories can release pollutants into waterways or produce greenhouse gas emissions, which contribute to climate change – these negative impacts impose a cost on society, which is not borne by the factories; it is an external cost. Emissions trading schemes are a method of removing externalities related to greenhouse gas emissions, as they impose an internal cost on firms for the greenhouse gas they release.

Framing: The initial analysis of a risk problem looking at what the major actors, e.g., governments, companies, the scientific community and the general public, select as risks and what types of problems they label as risk problems. This defines the scope of subsequent work [IRGC, 2005].

Hazard: A source of potential harm or a situation with the potential to cause loss [Australian/New Zealand Risk Management Standard, cited in IRGC, 2005].

Knowledge: The Concise Oxford English Dictionary defines knowledge as: (i) information and skills acquired through experience or education; the sum of what is known (ii) awareness or familiarity gained by experience [OED, 2008]. The classical definition of knowledge, as formulated by Plato, is “justified true belief”. However, epistemologists continue to debate the meaning of “knowledge” and, as such, there is no agreed-upon definition.

Organisational capacity (assets, skills, capabilities): The ability of organisations and individuals within organisations to fulfil their role in the risk governance process [IRGC, 2005].

(Risk) Mitigation: Measures to reduce the impact of a realised risk [IRGC, 2005].

(Risk) Perceptions: The outcome of the processing, assimilation and evaluation of personal experiences, values or information about risk by individuals or groups in society [IRGC, 2005].

Risk: An uncertain (generally adverse) consequence of an event or an activity with regard to something that humans value [definition originally in Kates et al., 1985: 21]. Such consequences can be positive or negative, depending on the values that people associate with them [IRGC, 2005].

Risk appetite: The amount and type of risk that an organisation is prepared to pursue, retain or take [ISO, 2009].

Risk assessment: The task of identifying and exploring, preferably in quantifed terms, the types, intensities and likelihood of the (normally undesired) consequences related to a risk. Risk assessment comprises hazard identifcation and estimation, exposure and vulnerability assessment, and risk estimation [IRGC, 2005].

Risk attitude: An organisation's approach to assess and eventually pursue, retain, take or turn away from risk [ISO, 2009].

Risk governance: The identifcation, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated, and how and by whom management decisions are taken.

Risk governance deficit: A defciency or failure in the identifcation, framing, assessment, management or communication of the risk issue or in how it is being addressed. Governance defcits are common. They can be found throughout the risk handling process and limit its effectiveness. They are actual and potential shortcomings, and can be remedied or mitigated.

Risk management: The creation and evaluation of options for initiating or changing human activities or (natural or artifcial) structures with the objective of increasing the net benefit to human society and preventing harm to humans and what they value; and the implementation of chosen options and the monitoring of their effectiveness [IRGC, 2005].

Risk tolerance: An organisation's or stakeholder's readiness to bear the risk after risk treatment (process to modify the risk) in order to achieve its objectives. (Note: Risk tolerance can be infuenced by legal or regulatory requirements) [ISO, 2009].

Systemic risk: Risks affecting the systems on which society depends. The term "systemic" was assigned by the OECD in 2003 and denotes the embeddedness of any risk to human health and the environment in a larger context of social, fnancial and economic consequences and increased interdependencies both across risks and between their various backgrounds [IRGC, 2005]. Systemic risks are characterised by complexity, uncertainty and ambiguity. Most often, they are also trans-boundary.

Stakeholders (in risk issues): Socially organised groups that are or will be affected by the outcome of the event or the activity from which the risk originates and/or by the risk management options taken to counter the risks [IRGC, 2005].

Securitisation (in the financial sector): The creation of asset-backed securities where debt obligations (such as mortgages) are pooled, with the resulting pool then being subdivided into portions that can be sold as securities on the secondary market.

Uncertainty: A state of knowledge in which the likelihood of any adverse effect, or the effects themselves, cannot be precisely described. (Note: This is different from ignorance about the effects or their likelihood) [IRGC, 2005].

Vulnerability: The extent to which the target can experience harm or damage as a result of the exposure (for example: immune system of target population, vulnerable groups, structural defciencies in buildings, etc.) [IRGC, 2005].

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Note:
All web addresses last accessed 28 October, 2009.

Acknowledgements

IRGC projects are led by its Scientifc and Technical Council, chaired by Granger Morgan (Head, Department of Engineering and Public Policy, Carnegie Mellon University, USA). Many of the initial ideas that led to IRGC's Risk Governance Defcits project and to this report were the result of discussions at meetings of the Scientifc and Technical Council. The steering committee that was specifcally in charge of leading this project comprised John D. Graham (Dean, Indiana University School of Public and Environmental Affairs, USA), Ortwin Renn (Professor for Environmental Sociology, University of Stuttgart, Germany), Joyce Tait (Innogen Scientifc Advisor, ESRC Innogen Centre, University of Edinburgh, UK) and Timothy Walker (Chair, Accounting and Actuarial Discipline Board, Financial Reporting Council, UK), each of whom contributed signifcantly to this report's text.

The principal authors of this report are John D. Graham, Beat Habegger (Senior Researcher, Crisis and Risk Network, Center for Security Studies, ETH Zurich, Switzerland) and IRGC staff members Belinda Cleeland and Marie Valentine Florin.

The authors and steering committee have received considerable editorial support from Martin Weymann (Vice President, Risk Management, Swiss Reinsurance Company) and Chris Bunting (Secretary General, IRGC). We also thank Linda Healey (Managing Project Editor, Creative Solutions, International Herald Tribune) for her assistance with the language of this report.

IRGC's reports are developed as a result of projects where experts are invited to contribute their knowledge and opinions. The authors have benefted from the many individuals and organisations who have shared their thinking during the project, particularly at two gatherings in November 2008 and June 2009 hosted by Swiss Reinsurance Company at the Swiss Re Centre for Global Dialogue, Rüschlikon, Switzerland.

The case-studies that were developed to illustrate risk governance defcits have been written by: Leeka Kheifets (Professor of Epidemiology, UCLA School of Public Health, USA), John Swanson (Scientifc Adviser, National Grid, USA) and Shaiela Kandel (School of Public Policy, Faculty of Social Science, Hebrew University of Jerusalem, Israel); Donald P. Moynihan (Associate Professor and Associate Director of the La Follette School of Public Affairs, University of Wisconsin-Madison, USA); Kjellrun Hiis Hauge (Institute of Marine Research, Bergen, Norway) and Douglas Clyde Wilson (Senior Researcher and Research Director, Innovative Fisheries Management, Aalborg University, Denmark); Joyce Tait; and Belinda Cleeland.

IRGC reports are the result of substantive project work by IRGC and are published only after a rigorous external peer review. Stefan Michalowski (Executive Secretary, Global Science Forum, OECD, France) acted, on behalf of IRGC's Scientifc and Technical Council, as review coordinator of a review in which the comments and critiques received from Philippe Jaud (Senior Research Engineer, EDF, France), Warner North (President, NorthWorks Inc., and Consulting Professor, Department of Management Science and Engineering, Stanford University, USA); and Marc Saner (Executive Director, Regulatory Governance Initiative, School of Public Policy and Administration, Carleton University, Canada), as well as from the participants to the June 2009 roundtable, coming from academia and the public and private sectors, led to a number of signifcant improvements in the text.

Finally, this project and report would not have been possible without the fnancial support of IRGC's donors, including the Swiss State Secretariat for Education and Research, the Swiss Agency for Development and Cooperation, the Government of Quebec, Alpiq Group, Swiss Reinsurance Company and Oliver Wyman Inc.

About IRGC

The International Risk Governance Council (IRGC) is an independent organisation based in Switzerland whose purpose is to help the understanding and governance of emerging, systemic global risks. It does this by identifying and drawing on scientifc knowledge and the understanding of experts in the public and private sectors to develop fact-based recommendations on risk governance for policymakers.

IRGC's goal is to facilitate a better understanding of risks; of their scientifc, political, social, and economic contexts; and of how to manage them. IRGC believes that improvements in risk governance are essential if we are to develop policies that minimise risks and maximise public trust in the processes and structures of risk-related decision-making. A particular concern of IRGC is that important societal opportunities resulting from new technologies are not lost through inadequate risk governance.

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ISBN 978-2-9700631-9-3