Emerging Risks in the 21st Century

AN AGENDA FOR ACTION

OECD

Emerging Systemic Risks in the 21st Century:

An Agenda for Action

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ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Publié en français sous le titre :

Les risques émergents au XXI^e^ siècle
VERS UN PROGRAMME D'ACTION

Foreword by the Secretary-General

Large-scale disasters of the past few years – such as the terrorist attack of September 11, 2001, the appearance of previously unknown infectious diseases, unusually extensive flooding in large parts of Europe, devastating bushfires in Australia and violent ice storms in Canada – have brought home to OECD governments the realisation that something new is happening. Such "mega-risks" have the potential for inflicting considerable damage on the vital systems and infrastructures upon which our societies and economies depend, and create serious difficulties for traditional risk management and risk-sharing actors, such as the insurance industry. Preparing to deal effectively with the hugely complex threats of the 21st century is a major challenge for decision makers in government and the private sector alike, and one that needs to be addressed as a matter of urgency. This report on emerging systemic risks is an important contribution by the OECD to a better understanding of the changing nature of risks and to identifying the kind of policy actions that will need to be taken.

Donald Johnston

Preface

What is new about major risks in the 21st century? Recent years have witnessed a host of large-scale disasters of various kinds throughout the world: hugely damaging windstorms and flooding in Europe and ice storms in Canada; new diseases infecting both humans (AIDS, the Ebola virus) and animals (BSE); terrorist attacks such as those of 11 September 2001 in the United States and the Sarin gas attack in Japan; major disruptions to critical infrastructures caused by computer viruses or simply technical failure. These are just some of the extremely costly disasters that have struck over the past few years. And yet, it is not just the nature of major risks that seems to be changing, but also the context within which they appear and society's capacity to manage them. The forces shaping these changes are many and varied. For example, weather conditions appear to be becoming increasingly extreme. The population density in urban centres and concentrations of economic activity in certain regions are rising, rendering these areas more vulnerable. Globalisation in all its dimensions – economic, technological, cultural, environmental – is growing apace and increasing interdependence, making it all the easier for dangerous pathogens, pollutants and technical failures to spread. Equally important, the frontiers of scientific discovery and technological innovation are expanding at breathtaking speed, confronting society with unknown (indeed, unknowable) impacts, and therefore immensely difficult choices. If the past is any guide to the future, these trends are set to continue.

This report, produced by the OECD's International Futures Programme (IFP), explores the implications of those developments for the economy and society in the 21st century, focusing in particular on the possibility of major systems becoming more vulnerable in the future. Health services, transport, energy, food and water supplies, information and telecommunications are all examples of sectors with vital systems that can be severely damaged by a single catastrophic event or chain of events. Such threats may come from a variety of sources, but the report concentrates on five large risk clusters – natural disasters, technological accidents, infectious diseases, terrorism-related risks, and food safety. It examines the underlying forces driving changes in these domains and identifies the challenges facing OECD countries – especially at international level – in assessing, preparing for and responding to conventional and new hazards. It also sets out a number of recommendations for governments and the private sector as to how the management of emerging systemic risks might be improved. Importantly, it advocates a coherent approach to management, and proposes policy tools for achieving that objective.

The project was carried out by an OECD Secretariat team in the International Futures Programme, which reports directly to the OECD Secretary-General. The IFP, created in 1990, has long experience in forward-looking, multidisciplinary activities that helped to lay the groundwork for this project. By organising international conferences and projects – with governments, business and civil society participating – on such themes as long-term prospects for the world economy, the future of international air transport, OECD societies in transition and 21st century technologies, it had the means and opportunity to track on an ongoing basis a wide range of future trends. Eventually and inevitably, attention came to focus on the changing nature of major systemic risks. Conceived and designed in 1999/2000, the two-year risk project – the first cross-sectoral study of its kind at the OECD – was completed at the end of 2002.

The work was overseen by a Steering Group whose membership (see Annex 1) consisted of high-level representatives from 19 governmental departments and agencies, seven corporations, and three international organisations. The Secretariat's work benefited considerably from substantive contributions provided by members of the Steering Group. It also benefited from the input of leading experts in the field of risk management (Annex 2) and from the knowledge and advice of colleagues in various OECD Directorates and Agencies (Annex 3), notably the Nuclear Energy Agency, the Directorate for Public Governance and Territorial Development, the Directorate for Science, Technology and Industry, the Environment Directorate, the Directorate for Financial, Fiscal and Enterprise Affairs, and the Directorate for Food, Agriculture and Fisheries.

This publication brings together the analytical work conducted as a key element of the project and the policy recommendations. The report reflects a broad consensus among the members of the Steering Group on the principal analytical findings and recommendations. Michael Oborne, the IFP's current Director, and Wolfgang Michalski, who directed the IFP until November 2001, chaired the meetings of the Steering Group. The initiator, promoter and co-ordinator of the project was Pierre-Alain Schieb; Barrie Stevens directed the preparation of the report and also wrote parts of it; Reza Lahidji was the principal author of the report, and co-ordinated inputs both from external experts and from the in-house support team. This team consisted of Patrick Love, Marieke Cloutier, Federica Marzo and Stefanie Kage. Anita Gibson assisted in promoting the project and, together with Geraldine Lynch, Marie-Ange Sicaire, Lucy Krawczyk and Concetta Miano, provided secretarial and logistical support. Randall Holden edited the text.

The publication is made available on the responsibility of the Secretary-General of the OECD.

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Introduction and Summary

Every day, people face a variety of risks that may result in damage to what they value: their life, their health, the lives and health of others, their property, or the environment. Some of these risks affect individuals but have only an isolated impact on society – car accidents are an example. Others, however, may be on a much larger scale and their effects may spread much further. This report is concerned with the latter, more specifically, with those risks that affect the systems on which society depends – health, transport, environment, telecommunications, etc. Five categories of such risks are addressed: natural disasters, industrial accidents, infectious diseases, terrorism, and food safety. The report does not deal with systemic risks to markets, notably to financial markets, although some aspects of financial systems are considered in the analysis.

Important changes to major risks are expected to take place in the coming decades. The forces driving change are many and varied, ranging from environmental and technological to demographic and socioeconomic. They are set to alter significantly a wide range of risks, and also the context in which such risks are managed. The Futures Project on Emerging Systemic Risks, conducted between 2000 and 2002 as part of the OECD's International Futures Programme, aimed to identify these trends and to propose a framework for studying and managing risks as they evolve in new directions. The findings of the Project are published in this report.

The approach and structure of the Report

The methodology adopted in the Project is an unconventional one. It uses a combination of approaches. First, it endeavours to tackle the issue of systemic risks in a future-oriented manner by examining the trends and driving forces shaping the risk landscape in the next few decades. Second, as the title of the Project indicates, it looks at the vulnerability of vital systems. And third, it examines a broad range of major risks across almost the entire risk management cycle, thereby aiming for a truly holistic approach.

Chapter 1 of the report sets out the scale of the growing problem of emerging systemic risks and the factors underlying their development. The increasing incidence and impact of natural, technological and health-related hazards are examined for a number of selected risk areas. This is followed by a review of the main driving forces and prospects for the changing nature and context of risks, which leads to the identification of a set of cross-cutting issues deemed critical for the management of risks in the years to come.

In Chapters 2 to 5, the key issues identified in Chapter 1 are examined in light of the implications they hold out for the various elements of the risk management cycle, i.e. risk assessment; risk prevention and mitigation; emergency management; and recovery issues ranging from business continuity, liability and compensation to experience feedback. Greater concreteness is added by integrating into each of the chapters five case studies that set the context for the analysis in five areas of risk management: flooding, nuclear accidents, infectious diseases, terrorism and food safety. Moreover, the report draws on a wide range of specific illustrations, from space technologies and the protection of critical infrastructures to xenotransplantations, the production of chemicals and tanker accidents.

Chapter 6 offers an action-oriented agenda for decision makers in the public and private sectors and elsewhere in society. It draws conclusions from the analytical work in preceding chapters – in particular, that emerging systemic risks require a systemic response – and recommends measures that aim to: adopt a new policy approach to risk management; develop synergies between the public and private sectors; inform and involve stakeholders and the general public; strengthen international co-operation; and make better use of technological potential, enhancing research efforts.

Driving forces and key issues

The changes likely to affect risks and their management in the coming years will occur in four contexts: demography, the environment, technology, and socioeconomic structures. These will reshape conventional hazards and create new ones, modify vulnerability to risks, transform the channels through which accidents spread, and alter society's response. Different forces acting on the same risk can neutralise each other's effects, or reinforce each other for a compound effect.

What forces modify systemic risks?

Demography

World population is projected to increase to 9 billion by 2050, versus today's figure of 6 billion. Practically all that growth will be in the developing countries of Asia and Africa. This will put increased strain on resources and systems that are already insufficient in many cases.

Those 3 billion additional people will almost all live in cities. Large concentrations of population and assets in megacities increase the potential

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impact of negative events, particularly where planning procedures are inadequate. In many cases these cities are already experiencing difficulties in providing basic services such as transport or waste treatment.

There are also significant changes in the age structures of populations. A third of the population in the developed countries will be aged over 60 by 2050 – versus 19% in 2000 – and a similar evolution is projected for the developing countries, in some cases at a later date. Older populations are more vulnerable to certain risks (*e.g.* epidemics), and their attitudes could have an impact on how risks are perceived and managed.

Finally, migration will probably intensify. At present, international migration mostly concerns population movements within developing countries. While these movements will continue to involve high numbers, by 2050 South-North migration might become the norm. Within developing countries, mass migration is often the direct result of extreme poverty and/or of a catastrophe (war, natural disaster), and in turn contributes to aggravating risks (*e.g.* through the propagation of infectious diseases).

The environment

The earth's climate is changing and will continue to do so. Human activities and related greenhouse gas emissions are increasingly understood to be the cause of global warming. Driven in particular by worldwide population and economic growth – and the underlying energy production and consumption patterns – CO_2 emissions are projected to increase by one-third in OECD countries and to double in non-member economies from 1995 to 2020. Meeting Kyoto targets will require reducing greenhouse gas emissions in OECD countries by 20% to 40% in 2020 compared with reference scenario projections. While the effects of global warming vary considerably from region to region, and may indeed be beneficial in some cases, the frequency and intensity of extreme events such as drought and storms is expected to increase.

Water will be increasingly scarce. Over half of the 12 500 km^3 of freshwater available for human use is already used and 90% will be used in 2030 if current trends continue. With present consumption patterns, two-thirds of the world's population will live in water-shortage conditions by the year 2025. Already today, 1.4 billion people do not have direct access to drinking water and over 3 billion people do not benefit from safe purification plants. Worldwide, polluted water is already estimated to affect the health of about 1.2 billion people and to contribute to the death of about 15 million children aged under five every year. Absence or inadequacy of sound water resources will increasingly play a role in weakening the health of populations and amplifying infectious disease outbreaks in the future.

Reduction in bio-diversity could well be another trend with dramatic consequences. Bio-diversity offers an ecosystem higher stability and resilience. In agricultural areas, it has been reduced by the intensification and uniformisation of crops. Changes in land use patterns also tend to reduce diversity, e.g. the draining of wetlands or clearing of forests.

Technology

Technological change can reduce some risks while aggravating others or even creating new ones. Three aspects of emerging technologies will influence risk: connectedness; the speed and pervasiveness of technological change; and the fundamental changes in the landscape they might induce.

Regulatory change and the development of transport, trade and information systems mean that many activities depend on the interaction of a variety of actors within networks, often at a global scale. With regard to risk this is positive, to the extent that information gathering and processing are facilitated, as are contacting victims and organising help. But connectedness also multiplies the channels through which negative consequences can propagate.

Successful new technologies may quickly replace those existing, and the need to conquer markets may supersede thorough consideration of all the implications. The scare surrounding the "millennium bug" illustrates how a seemingly innocuous decision (in this case the way dates appear in computers) could have far-reaching consequences many years ahead.

Some emerging technologies change living matter, and represent an unprecedented potential to change the environment. They are even starting to challenge the definition of "living", and could ultimately change the whole notion of "human". While the hope is that biotech (for instance) will improve living conditions and the quality of life, it can be argued that the long-term consequences of interfering at such a basic level are impossible to evaluate given the present state of knowledge. Some could also argue that irreversible damage could be done before the danger is understood or when it is too late to stop it.

Socioeconomic structures

Vulnerability to and perception of risk in society are evolving. Government's role in directly managing the economy has been shrinking over several decades, and especially in the past twenty years – through privatisation, deregulation and regulatory reform. Attitudes and policy are increasingly influenced by international bodies, corporations, and non-governmental organisations as well as by government, and risk management can be impaired by conflicts of interest among the various actors.

In some sectors, globalisation, competition and technological change encourage larger scales and higher degrees of economic concentration. This can increase vulnerability to shocks if a vital component is damaged and no alternative is readily available.

Poverty has persisted and in some cases increased in recent years. The living conditions of the poor render them more exposed to risks, but poverty and income gaps also have indirect impacts on risk, in that they fuel social tensions and weaken the social cohesion needed to assess and respond to potential dangers.

Finally, the public's perception of risks depends on the mass media rather than on expert opinion, and the tendency in these media is shifting away from information and towards entertainment. As a result, issues are framed in terms that are readily assimilated rather than informative (mad cow disease for bovine spongiform encephalopathy, Frankenstein foods for foods containing genetically modified organisms). Poor communication can turn a crisis into a major disaster, especially if decision makers are slow to react or are discovered to have lied.

What issues do these forces raise for the future of risk management?

The influence of these forces on risks and risk management in the future is expected to be complex. To have a holistic view of their dynamics, it is important to identify the key issues that could challenge risk management. These fall under five headings: heightened mobility and complexity; increasing scale and concentration; a changing context and major uncertainties; shifting responsibilities; and the importance of risk perception.

Heightened mobility and complexity

The openness and connectedness of systems and the mobility of people, goods, services, technology and information increase the number of potential interactions that can generate or influence a hazard. Risks become more complex. At the same time there is greater awareness of the complexity of the world itself (*e.g.* of natural or social processes), and of the need to better account for that complexity when considering risk issues.

A number of methodologies have been developed to cope with such complexities. Some methods used to assess and manage safety inside complex engineered systems, for instance, adopt a comprehensive approach to risk. In particular, they emphasise the transmission mechanisms through which a hazard spreads and amplifies, as well as the variety of consequences it generates, in both the short and long terms. This report uses a similar approach to analyse the challenges facing risk management in the years ahead.

Increasing scale and concentration

A number of current evolutions point towards reduced diversity and increasing scales, in domains such as the economy (market concentration), urbanisation (megacities), and the environment (loss of bio-diversity). Diversity helps the management of risks by spreading them over space and time. Concentration, on the contrary, aggregates risks, and often makes them more difficult to manage. Therefore, the consequences of concentration in terms of vulnerability to major hazards might become a major issue in coming years. Policies promoting diversity and differentiation could present themselves as necessary complements to existing risk management strategies, for instance when it comes to critical infrastructures. Risk management tools (from backup facilities and rescue services to insurance schemes) will have to be adapted to the large-scale disasters that could occur as a result of concentration. Governments will have a crucial role to play in developing adequate tools.

A changing context and major uncertainties

As a result of the variety of forces described above, many hazards could change in the near future with regard to their frequency or to the damage they could cause. Floods, infectious diseases and terrorist acts are only three examples of the many risks that have seemed to depart quite significantly from past records in recent years. Therefore, if risk management is essentially based on past experience – as is often the case – it could be confronted with numerous "surprises". Risk management strategies need to better incorporate forward-looking methods, and in particular to evaluate and understand the impact of the driving forces of change.

In some cases, however, monitoring ongoing evolutions in risks can be an impossible task for science. Such is the case, for instance, when a new technology like xenotransplantations emerges, or when complex processes such as the global climate are at work. Risk management might be faced with major uncertainties more often than in the past, and will therefore need an adequate framework to deal with these cases.

Shifting responsibilities

The changing role of the state as well as decentralisation and societal change have deeply modified governance in all OECD countries, notably in the area of risk management. While the traditional management modes are thus probably less effective, a new policy framework has not yet been properly defined. A large range of tools are available for risk policy – from provision of information and partnerships to fiscal incentives and tort law – but their efficient use is a challenge in itself. Some tools need to be further developed and enhanced. New roles and responsibilities in handling risks and ensuring safety will need to be adequately defined and enforced. This will entail, in particular, clarifying the reasons for risk management failures, and understanding the influence of general organisational and environmental factors.

In addition, many emerging systemic risks are global by nature. This means that national strategies will likely face serious difficulties, and that international solutions adapted to each case will need to be developed, from exchange of best practices and co-operation to more binding agreements.

The importance of risk perception

Nowadays, attitudes towards risk can constitute a major part of the risk issue. In cases such as the bovine spongiform encephalopathy crisis of the late 1990s in Europe, for instance, a large share of the total costs incurred were due to society's reaction to a perceived risk rather than to the physical reality of the risk itself. At the same time, the traditional view according to which people have irrational attitudes towards risk and the role of policy is to educate them has lost some ground.

Risk issues are now understood as complex social issues, where a variety of stakeholders can have differing – though equally legitimate – standpoints. How the diverse views are considered and integrated into policy making, how issues and decisions are communicated, and how the media and society at large receive and use that information have become integral components of risk management.

Risk assessment

Risk assessment consists in identifying and evaluating each step of a trajectory – from the origins of a hazard to its final consequences for a given system. It is an essential element for deciding whether and how risk needs to be avoided, reduced or accepted. Both as a scientific process and as input for decision making, assessment of emerging systemic risks faces a number of challenges.

Difficulties in assessing risks scientifically

Risk assessment has gradually mobilised a large amount of scientific knowledge sourced in a variety of disciplines, and developed sometimes sophisticated and increasingly reliable methodologies and tools. Notwithstanding these achievements, a number of limitations are likely to lead to difficulties.

- Existing assessments are based on models, which are sometimes far from reproducing real-world conditions accurately. In many risk areas, for instance, the model is a recording of past occurrences rather than a formal evaluation of the various upstream interacting processes influencing risk.

But in a context where underlying conditions are changing, past experience might be misleading.

- Equally, most models assume a more or less linear relationship linking a hazard from a well-identified source to a single endpoint; they thus appear inadequate to explain and predict complex phenomena.
- Long-term consequences and impacts outside the system studied are usually neglected, since the system is assumed to be self-contained in space (physical or operational) and time.
- Human behaviour is a prevailing risk factor in most cases, but is difficult to evaluate. Faced with that difficulty, existing assessment methods often ignore human factors or use simplistic or standardised models of behaviour. When analysing the causes of accidents, it is tempting to concentrate on what is readily identifiable and quantifiable – *e.g.* the actions of a final operator who "causes" the accident – and to neglect aspects that might be more important but are difficult to quantify, such as organisational structure.

As these examples show, risk assessment must recognise the plurality of factors involved, some of which are undergoing fundamental change, and account for the range of impacts risk can have. This means that risk assessment will need to combine knowledge coming from a larger variety of disciplines and areas of expertise, and pay increased attention to changing conditions. On a technical level, improved methods are gradually emerging, such as integrated approaches that can cope with interactions and nonlinearity; probabilistic methods that allow variability and uncertainties to be incorporated; and geographical information systems that can provide socioeconomic data on populations at risk and help manage information at the appropriate scale.

A risk management decision framework

But adequate understanding of a given risk is not an end in itself. It is an input – among others – to decision making. Indeed, the task of the decision maker is to determine the level of risk that is appropriate from the community's standpoint in a situation where resources are limited and scientific understanding of the issue may be incomplete and opinions and interests contradictory. As recent examples of emerging systemic risks show, the task could gradually become extremely challenging.

- It is important that resources for risk reduction are allocated as efficiently as possible. As it happens however, rationalising the use of resources (for instance through cost-benefit analysis) is often hampered by scientific uncertainty and by the absence of consensus in society as to the value issues involved.

- Risk assessment has to deal with various kinds of uncertainty. Because of the complexity of causal relations and gaps in data, emerging systemic risks often can involve large gaps in the very understanding of the phenomena at work. This kind of uncertainty, which often goes hand in hand with scientific controversy, is extremely difficult for policy makers to address.
- The proponents of a "technical" approach to risk management have long considered that the public's perceptions were unfounded and should not interfere with the objective assessment of risks. At the same time it is increasingly accepted that although the public perception of risk can be wrong (for instance if it is distorted by orchestrated campaigns by vested interests), there is no objective and unique measure of risk. Risk has a multitude of dimensions, some of which involve ethical considerations. A number of different views can thus be pertinent and legitimate, and confronting this variety of standpoints is part of risk management.

To address these issues, decision-making tools and processes need to clarify the respective contributions of facts, values, and uncertainties. They also need to satisfy more than one objective (*e.g.* using resources efficiently and meeting public expectations), and often in a situation where the different objectives are competing. It is possible to develop a framework for dealing with uncertainty and conflicting values and interests while trying to maintain consistency. Three components form the basis.

The first is the notion of precaution, as set out in the 1992 Rio Declaration on the environment and development: "Where there are threats of serious and irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". Two pitfalls have to be avoided when putting into practice the notion of precaution: using it as a substitute for scientific risk assessment, and using it as an alibi for circumventing agreements on free trade. An international understanding of precaution-based strategies of risk management is required, notably their legal aspects.

The second element is decision analysis, a methodology for systematically evaluating the various facets of a decision problem. Decision analysis has the advantage of determining the acceptable level of risk within the context of the problem, in conjunction with the best management option for this context. In that framework, there is no established preference for one particular conception of risk, or for one type of solution (*e.g.* technical responses rather than trust building).

Thirdly, it is increasingly acknowledged that risk assessment must encompass a wide spectrum of possible harms and losses, and recognise that the interests and attitudes of elected officials, experts, the public and firms may be very different. Where a consensus cannot be achieved, the minority is more likely to support the final decision if it has been involved in the decision-making process. This process should involve the two discrete but linked aspects of analysis and deliberation.

Risk prevention

Risk prevention and mitigation aim at preventing accidents and disasters, or at reducing their consequences before they occur. This can be achieved by protecting systems and reducing their vulnerability to specific hazards on the one hand, and by improving the way society handles risk through an enhancement of its safety culture on the other.

Protecting systems in advance

Protective strategies of prevention can use a variety of tools: early warnings and alert procedures, various forms of shields, redundancies, backup mechanisms, etc. They will face a number of challenges in the future: more extensive and timely information will be needed; both domestically and internationally, co-operation and co-ordination will have to be intensified; backup schemes will have to be developed more thoroughly in key systems; the resilience of critical infrastructures will become crucial.

Common factors across the entire spectrum of emerging systemic risks are the need for information gathering, early warning, and timely identification of vulnerabilities. In some areas – *e.g.* nuclear accidents, natural disasters (hurricanes, flooding) and infectious diseases – a number of sound monitoring and early warning mechanisms are in place, especially in developed countries.

The growing interdependence of economies and societies across the globe, however, means that emerging risks in developing countries, where monitoring and early warning systems are often inadequate or nonexistent, can rapidly spread. That makes it imperative to strengthen international co-operation and co-ordination so as to transfer knowledge, skills and technologies and thereby close potentially dangerous loopholes in the overall coverage of the monitoring effort. The prospect of new threats in the form of drug-resistant diseases, cyber-terrorism, bioterrorism, etc. only serves to underscore this urgent need.

Measures to protect systems or at least boost their resilience to disruption and/or attack fall into two broad categories: steps designed to strengthen vulnerable points in the system (*e.g.* constructing dams, building protective shells around nuclear power plants), and steps to make the "architecture" of the system, an increasingly key element, more resilient.

In both critical infrastructures and other complex systems such as hospital centres, the presence of redundancy in the system can be key to its

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robustness. Thus, in case of failure of the primary mechanisms or processes (*e.g.* disruption of fully automated air traffic control, failure of front-line safety mechanisms in nuclear power plant operation, swamping of emergency medical facilities), backup systems are available to take up the strain. However, to the extent that tighter criteria of economic efficiency apply in overall economies, the principle of in-built system redundancy may be called increasingly into question.

Terrorist attacks, cyber-crime and certain natural catastrophes highlight the need to design critical infrastructures with their growing interdependence in mind. Particularly in energy, information/communications and transport, even minor disturbances can snowball into major disruptions. Among the issues examined in this chapter are the growing reliance in some activities on commercial, highly standardised off-the-shelf technology; lack of diversity in system providers; and the security trade-off involved in decisions to centralise or decentralise networked systems.

Framework conditions of risk prevention

Society's success or failure in managing risk is not only a question of specific prevention and mitigation measures, but also of its "safety culture", its attitudes towards risk and safety at every level of decision making. In practice, it is often difficult to have a holistic view on safety because each of these levels is scrutinised by a different discipline. Safety culture is shaped by a multitude of factors, such as the manner in which safety regulations are implemented and enforced, the risk-related impacts of taxes and subsidies, tort and liability law, insurance and information on risks.

Frameworks for managing risk range from centralised command-and-control methods to decentralised self-regulation. Although these frameworks can vary widely from one country or risk area to another, they are nearly all influenced by two developments. First, centralised modes of risk management have become less effective. The command-and-control approach emphasising individual compliance to rules are less adapted to modern, largely decentralised economies and societies. In particular, complexity makes work flows and production processes difficult to break down into readily codifiable items, as needed in top-down safety procedures. The second major trend is a greater role for tort law and insurance, which seek to create optimal incentives with regard to attitudes towards risk *ex ante* (*e.g.* prudence dictated by the prospect of being found liable), and provide redress to victims *ex post*. Liability exposure is nowadays increased by a number of legislative developments, and more frequent appeals to the tort system within an emerging "claim culture".

In such a context, systemic risks create particular challenges for risk management.

- Individuals and organisations have greater responsibilities in the management of risks, but are often not aware of these responsibilities, or not sufficiently informed about risks. Risk awareness and preparedness have become more important than they were in the past. Within a system, this means in particular that information has to be shared in real time among all the relevant actors, to provide feedback on the safety implications of decisions and to enable realistic safety boundaries to be established.
- Safety contributes to competitiveness in the long term, but costs related to safety expenditures are usually immediate, while benefits only materialise through time. Therefore an increase in competitive pressure can mean a reduction in the safety budget, leading to poorer safety performance. Particularly in public utilities, it is often necessary to clarify the regulatory framework with regard to safety obligations.
- This last point also applies to governments. Faced with fiscal constraints, they may be tempted to reduce spending on activities such as infrastructure maintenance or training of personnel; that impact may not be felt in the short term, but can over time lead to a significantly reduced ability to manage risks. In addition, some existing policies actually increase risk, *e.g.* tax policies or subsidies that lead to harmful consequences for the environment.
- Recent evolutions in tort law aimed at improving compensation of victims (notably the weakened concept of negligence) might gradually reduce incentives for risk prevention. In many cases, liabilities established *ex post* by courts are quite difficult to predict *ex ante*. When liability has not been anticipated, as with retroactive applications of law, tort law no longer holds its preventive function. On the other hand, serious potential risks linked to the development of new products and techniques cannot be ignored. In some cases the possibility of retroactivity creates a reasonable incentive, as long as it is clearly stated *ex ante*.

Emergency management

Effective response will depend not only on actions immediately prior to, during and in the aftermath of a disaster but also – importantly – on pre-existing plans, structures and arrangements for bringing together the efforts of government and voluntary and private agencies in a comprehensive and co-ordinated way. Challenges for the future can be grouped around the following themes: the use and potential of new and emerging technologies for collecting and spreading information; the importance of effective monitoring and surveillance; planning and co-ordination of emergency responses; managing

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the media; containing damage propagation once disaster has struck; and international co-ordination of emergency operations.

Collection of/ access to information

New technologies, in particular high-performance and distributed computing, satellite observation and imagery, mobile communications, and the Internet hold the prospect of significant benefits to emergency management if their potential contributions can be realised. But those employing them face a number of obstacles – uneven distribution and access, possession of the requisite skills, the technologies' systemic vulnerability and lack of reliability in emergencies and, last but not least, their frequent inability to furnish data and information that are comprehensible and of use to practitioners on the ground.

Effective surveillance

Those and other technologies form part of the world's much enhanced capacity for hazard surveillance. However, despite considerable progress in surveillance structures in areas such as chemical and nuclear hazards, weaknesses remain – particularly when it comes to relatively new systemic risks such as terrorism and emerging infectious diseases. Where surveillance systems for such new risks are based on pre-existing structures that are themselves deficient (such as fallible national health systems), the risks and challenges for the future may well be magnified.

Efficiency and effectiveness of emergency services

Planning and co-ordination of emergency operations pose other issues. Although response can only be anticipated and planned to a certain extent, a number of generic conditions contribute to increasing its effectiveness: risk awareness within the community, familiarity and regular interaction among the various organisations responsible for emergency operations, trust and confidence in the relevant decision-making authorities, and political leadership. Still, emerging systemic risks such as bio- and cyber-terrorism or new infectious diseases could pose particular challenges to the planning and co-ordination of emergency responses. In part this is because the sheer scale of the disaster may place intolerable strains on the emergency services, incapacitate those involved in the operations and, more fundamentally, call for more innovative approaches to problems of logistical complexity, timeliness of damage containment measures, and so on. In part, however, new risks may also imply higher levels of decision making, *i.e.* at national and international levels.

Communication with the public and the media

The difficulty with the (inevitable) involvement of the media in disasters is that it tends to be a two-edged sword: on the downside, they may converge on the disaster site and hamper emergency operations, contribute to the propagation of disaster myths, or release erroneous reports; on the positive side, they may be essential for disseminating warnings or communicating information on mitigative action. The key with media would appear to be for authorities to build positive relationships in planning and operations at a very early stage, notably the disaster preparedness phase, and to have clear and coherent plans for interacting with the media as a disaster unfolds.

Disaster containment

In the damage limitation phase, two factors stand out. The first is the continuing assessment of the situation through efficient, dependable information collection and analysis. The second is the resilience of the emergency management systems, organisations and mechanisms to the impact of the disaster, for instance the coping capacities of primary health care or the reliability of mobile communications.

International co-ordination

Finally, as the globalisation process links countries, markets, sectors, people and cultures ever closer together, co-ordination of disaster response at international level takes on particular importance. Clearly there are still many problems related to matching the international response to the severity of the emergency, providing timely information to partner countries, addressing legal issues raised by emergency co-operation, etc. Reasons may be poor informational infrastructure or notification, tardy co-ordination of relief operations leading to under-response, unco-ordinated relief measures resulting in over-response, or the absence of guidelines and structures for minimising the disaster spillover effects on other countries.

Recovery issues

Recovery issues considered in the report are related to minimising the final costs of a disaster once it has struck, and after emergencies have been treated. Psychological and societal impacts have to be managed smoothly. Liabilities and compensation have to be determined as quickly and equitably as possible, and the availability of affordable insurance coverage needs to be secured. Finally, lessons have to be drawn from past inadequacies and failures.

Recovering from a disaster

Emerging systemic risks frequently create new challenges for recovery management due to their novelty and the extent of damage they cause. For example, secondary consequences can be much more devastating than direct ones because of the inability of certain parts of the economy to return to normal functioning, and because the public may "amplify" the risk by withdrawing trust in the authorities or stigmatising a product or technology, as happened to beef during the BSE crisis. Two issues are key to coping with the trauma of a disaster and minimising indirect costs: ensuring that systems vital to business continuity are not disrupted; and preventing panic, restoring trust, and avoiding stigmatisation.

- Insurance is reaching its limits as a response to business interruption because of the scale of potential losses and the indirect aspects that are not covered. Risk management strategies are thus increasingly based on business continuity, which depends to a large extent on avoiding disruption to vital systems (health, energy, telecoms, etc.). But even in OECD countries, vital systems may not always have the capacity to cope with the consequences of a large-scale disaster. Given the interconnectedness of the various components of the economy, the economic consequences of a single failure can spread widely beyond the immediate geographical area or business sector directly hit. Business continuity plans thus require a broad range of partnerships – both geographically, since international co-operation may be needed, and organisationally, to mobilise resources from public agencies, NGOs, private firms, the armed forces, etc.
- Accidents are often perceived as a betrayal of trust, and the social amplification of risk is closely linked to how the public perceive the risk management authorities. Trust has to be founded on information, education, and protection. Communication that merely provides quantitative information to prove that fears are exaggerated will generally have little impact. Communication strategy has to understand how the fear is generated and why it spreads. Steps should also be taken to prevent events that lead to stigmatising, even if this means investing sums beyond what formal cost-benefit analysis would indicate. Educating the media and risk managers about the origins and consequences of stigma is primordial. When stigma cannot be prevented, its victims should be protected, *e.g.* by guaranteeing a minimum price for healthy livestock during an epidemic.

Insurance issues

The past twenty years have seen a dramatic increase in insured losses, due to several factors: better insurance coverage, broadening of the concept of liability, the growing scale of some disasters, etc. This trend may threaten the long-term ability of the insurance industry to provide cover for cases involving large-scale losses due to natural, industrial and (now) terrorism-related causes. This is complicated by the fact that most emerging systemic risks are difficult to predict and damage involves uncertain causal relationships, while actuarially fair premiums are particularly difficult to determine. Moreover, past experience is of little help in predicting future occurrences. The 11 September attacks on New York and Washington illustrated how difficult it gets to provide insurance against emerging systemic risks, which are difficult to predict, offer little scope for diversification, and require huge financial capacity.

Possible strategies for the insurance industry include:

- Liability caps, which do not allow for complete compensation and may not fully internalise the costs of harmful activities.
- Using financial market instruments that transform existing insurance contracts into securities.
- Adapting policy conditions, *e.g.* by excluding certain risks or stipulating that the contract may be annulled by future changes in liability law.
- Having recourse to public intervention through the introduction of compulsory insurance for specific branches, the establishment of public or semi-public pooling arrangements, and the call for the state to act as an insurer of last resort.

Learning from disasters

- In the aftermath of a disaster, the attention of the public and the media are at their highest point. A unique window of opportunity then opens for improving the knowledge of new risks, for overcoming inertia and resistance in order to improve the assessment and management of risk, and for avoiding the recurrence of similar disasters.
- Learning from disasters entails analysing all phases of risk management in the light of experience, and answering questions such as:
- Are there any precursors to the occurrence of a hazard, and how can they be observed in the future?
- Did the occurrence of the hazard correspond to earlier assessment?
- How did the disaster spread, and whom did it affect?
- How did people react, and were warning signals received?
- Were there any unexpected factors of vulnerability?
- Which social and economic trends contributed to creating vulnerabilities, and can they be better managed?
- Which protections failed, if any, and why?

- Were there effective incentives to avoid or mitigate risk, and in particular was the legal framework conducive to appropriate risk prevention?

Beyond examination of such questions, however, systematically organising feedback and ensuring that corrective measures are actually taken can prove particularly challenging. In the case of major infectious diseases, for instance, important lessons have been learned that yield very encouraging results when applied. However, implementing them more systematically continues to face numerous problems.

Conclusions and recommendations: An action-oriented agenda

The analysis presented in the foregoing chapters provides general recommendations for action in five major directions. Together, these constitute a framework for a systemic response to emerging systemic risks:

1. Adopt a new policy approach to risk management.

- *Adopt a broader view on risk.* For instance, place additional emphasis on bringing together specialised knowledge in every aspect of risk issues (from "hard" sciences to psychology, sociology and economics), both by building more diversified competencies within risk management structures, and by enhancing dialogue between scientific disciplines.
- *Examine policy consistency across risk areas.* Develop decision improvement processes aimed at targeting an accepted level of risk; prioritise risks; and exchange information and share best practices among sectors.
- *Improve the coherence of risk management.* It is in particular necessary to improve understanding of how the various elements of regulation (or the absence thereof) shape behaviours and contribute to the final risk picture. Only on the basis of such an improved understanding can a strategy for risk management be defined consistently, and the most appropriate mix of risk policy instruments be chosen.

2. Develop synergies between the public and private sectors.

- *Get the incentives right.* Take account of the consequences policy measures could have for risk behaviour as a constant element of policy design. Equally, clarify the legal frameworks surrounding a producer's liability and responsibilities in risk assessment when a new product or technology is marketed.
- *Enhance the role of the private sector in risk management.* Encourage self-regulation as a complement to traditional control measures, notably by developing dialogue between regulators and operators to ensure that rules and norms are appropriate.
- *Address the issue of increasing scale through co-operation and promotion of diversity.* Infrastructure, public procurement and competition are policy

areas (among others) where governments could effectively support diversification and combat the heightened vulnerability that may be associated with concentration.

3. Inform and involve stakeholders and the general public.

- *Develop risk awareness and a safety culture.* The development of a safety culture requires information not only to be accessible to local authorities and the general public, but also to be usable and actually used by them. The media, schools, hospitals, and NGOs can play important roles in that respect, but public authorities have a leading role to play through adequate risk communication, notably during the window of opportunity opened by a disaster.
- *Enhance dialogue and build trust.* Ensure, through institutional arrangements, that risk assessments are credible – *i.e.* based on solid grounds, effectively communicated, and free of any link to policy decisions. At the same time, make it clear that scientific assessment although the basis of risk assessment, is one of several inputs in decision making, and that the quest for the best expertise should not delay action.

4. Strengthen international co-operation.

- *Achieve better sharing of knowledge and technologies across countries.* Contribute to closing the gap in capacity to manage major risks between advanced and developing countries by gradually expanding information- and technology-sharing agreements to new players.
- *Enhance international systems of surveillance and monitoring.* For example, co-ordinate regular exchanges of views and experiences among countries on improving public health services' effectiveness in preparing for and dealing with emerging systemic risks.
- *Create frameworks for co-operation.* Design or expand, on a case-by-case basis, co-operation mechanisms conducive to multilateral dialogue and to an internationally consistent assessment of risks. On controversial issues, for instance, what is required is advice from an international scientific committee, founded on irrefutable expertise and genuinely independent.

5. Make better use of technological potential and enhance research efforts.

- *Improve support for promising new technologies.* Review the interface between the public-good characteristics and the commercial dimension of key technologies, such as communication means, remote sensors, satellite launchers and space applications. Explore in particular whether new business models and new public-private partnerships are required.

- *Explore and develop tools that reduce the vulnerability and increase the resilience of systems*. Inter alia, develop technological tools to detect and reduce structural weaknesses in key installations infrastructure (dams, bridges, railways, etc.), in particular remote sensing technologies.

In addition, the report identifies a set of areas where further OECD work can contribute to better addressing the challenges created by emerging systemic risks. Among these, the report proposes that the OECD carry out a series of voluntary country reviews on risk management, focusing on the consistency of related policies and on their ability to deal with these challenges, present and future.

ISBN 92-64-19947-0
Emerging Systemic Risks in the 21th Century
Emerging Systemic Risks

Chapter 1

Emerging Systemic Risks

Abstract. *This chapter sets out the scale of the growing problem of emerging systemic risks and the factors underlying their development. The increasing incidence and impact of natural, technological and health-related hazards are examined for a number of selected risk areas. This is followed by a review of the main driving forces and prospects for the changing nature and context of risks, which leads to the identification of a set of cross-cutting issues deemed critical for the management of risks in the years to come.*

Executive Summary of Chapter 1

Risk refers to the combination of two factors: the probability that a potentially harmful event will occur; and the potential damage such an occurrence would cause. This report is interested in a category of risks that has received considerable attention in OECD countries in recent years, namely systemic risks. A systemic risk, in the terminology of this report, is one that affects the systems on which society depends – health, transport, environment, telecommunications, etc.

According to more than one measure, the damage caused throughout the world by many major risks appears to have increased in recent decades. The impact of natural disasters, especially floods, storms and droughts, has risen steeply since the early 1960s. In the past decade alone they have resulted annually in 79 000 fatalities and affected 200 million people. Numerous infectious diseases, some of which were long thought to have been conquered, are staging a comeback, and new ones are emerging with devastating effects in some parts of the world. Technological disasters such as explosions, fires and transportation accidents have also evolved rapidly since the early 1970s, with annual fatalities over the last decade averaging 8 000. According to some estimates, total financial costs arising from disasters have risen from USD 2 billion to USD 70 billion a year between the 1960s and 1990s.

Significant changes have occurred in recent years in the nature of major risks, and further changes can be expected in the future – both in the range of risks themselves, and in society's capacity to manage them. The forces at work are varied, ranging from demographic, through environmental and technological, to socio-economic:

- *World population is expected to rise by 50% in the next fifty years. The bulk of the increase will occur in developing countries, in particular in large urban centers, often with poor sanitary conditions. Populations will become substantially older, in particular – but not only – in OECD countries. Migration may intensify, due to economic motives, or to deterioration of the environment.*
- *Global warming will continue, and will lead to increased precipitation and to more frequent extreme climatic conditions in many regions of the world – be it droughts, storms or floods. Freshwater reserves will come under increased pressure and competition, and biological diversity may decrease.*
- *The frontiers of scientific discovery and technological innovation will continue to expand at breathtaking speed, sometimes before all of their implications have been thought through. Emerging technologies in the area of life sciences alter living*

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matter – and therefore have the potential to change the environment – on an unprecedented scale. Connectedness will be enhanced with the development of trade, transportation, and communication throughout the world.

- *Competition and technological change will lead to higher concentration and larger scales in some economic sectors. Income inequalities and pockets of poverty could well persist both within and between countries. And in countries where the role of the State has been modified by privatization and deregulation, where actors ranging from NGOs to international organisations have a growing influence, and where the media contributes to shaping public opinions, the context of governance will be radically different from the past.*

Such forces of change can be expected to give rise to five critical issues for risk management in the future:

- *With heightened mobility of people, goods and services, capital, and information, risks are becoming more complex, i.e. subject to a greater number of influences. At the same time, our understanding of the complexity of natural and social phenomena is improving. In order to cope, risk management has to develop new approaches and tools, such as those used in the management of safety within large engineered systems.*
- *Concentration and increasing scale aggregate risks. The various phases of risk management, from emergency services to insurance schemes, have to adapt to the increased possibility of large-scale disasters in the future. At the same time, the costs of and alternatives to concentration look set to become important issues for risk management strategies.*
- *As underlying conditions of risk – from climate to pathogen resistance – change, risk management policies based on past records and experience are likely to be increasingly faced with "surprises". How to account for evolving conditions will become a central issue in the handling of many risks. This will entail, in particular, a framework for dealing with major uncertainties and gaps in scientific knowledge.*
- *Roles and responsibilities in the management of risks have been modified by regulatory reform and societal change. This generates two major issues for the future of risk management: first, defining clearly who is in charge of safety and clarifying the influence of various economic and social factors in the safety performance of organizations; second, adapting the use of many varied policy tools to this new context, from provision of information to tort law.*
- *Social attitudes toward risk are becoming by and of themselves an important element of risk issues. Risks increasingly need to be managed in a way that is commensurate with societal views and perceptions. This entails a better understanding and evaluation of risk perception, and establishing two-way communication channels between risk managers and stakeholders.*

The implications of each of these critical issues for the various elements of the risk management cycle are explored in the following chapters of the report.

1. What are emerging systemic risks?

Risks are a major public concern in OECD societies today. The health consequences of Bovine Spongiform Encephalopathy (BSE), the link between climatic "accidents" and global warming, the vulnerability of information systems to external attacks, and the security of genetically modified foods are but a few examples of important risk debates that have emerged in recent years. Reactions to such risks, whether actual or perceived, have had considerable economic, social and even political consequences in numerous countries.

Looking further ahead, the indications are that major disasters of various kinds are more likely to occur. Many conventional risks look set to take on new forms, and new major hazards are emerging – some characterised by both extreme uncertainty and a potential for extensive and perhaps irreversible harm. These trends point to a marked future increase in the probability of major vital systems (technological, infrastructural, ecological, etc.) being severely damaged by a single catastrophic event (natural or man-made), or a complex chain of events.

The emphasis of this report is on such risks. It is this particular focus, together with the need for a holistic approach to risks in the future, that underlies the notion of emerging systemic risks. Defining more precisely what constitutes an emerging systemic risk entails some clarification as to what is meant by risk, a challenging task.[1]

In the simplest of terms, risk refers to potential damage caused by a single event or series of events. More technically, however, risk can be considered the combination of two factors. First, there is the probability of the occurrence of a hazard: a potentially harmful event which might itself be influenced by various factors. To the extent that events are reasonably predictable in their timing, location and scale, they are not considered in this report to be hazards but rather trends or evolutions shaping the development and context of hazards (the case, for example, with ageing populations and climate change). The second factor, vulnerability, reflects the potential damage inflicted by the occurrence of a hazard in terms of both direct and indirect consequences. Departing from such a broad definition, the report focuses on a specific kind of risks, *i.e.* on particular categories of hazards and vulnerabilities.

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Hazards come in many forms. At one end of the spectrum there are those that threaten the functioning of markets, the stability of macroeconomic conditions (inflation, unsustainable public finances) or political stability. These are not the concern of the present report. It is the other end of the spectrum that is of interest here, namely threats to health and human life, property, infrastructures and the environment.

By extension, *vulnerability* is a measure of the exposure of human lives, health, activities, assets or the environment to the potential damage caused by such hazards occurring. The source of the hazard may be a natural disaster or a technical accident; it may be related to a new disease or be attributable to terrorist activity. In the approach adopted in the report, therefore, vulnerability covers both the overall extent of the exposure to a hazard, and the degree of damage that is likely to be experienced if the hazard materialises.

The impact of harm to individuals and their property, or of damage to vehicles, plant and equipment or local stretches of land or water may of course be significant. More important, however, from the point of view of highly organised modern societies is the potential damage to the *systems* on which they increasingly depend. The provision of health services, transport, energy, food and water supplies, information and telecommunications are all examples of vital systems. The report does not focus attention on the financial systemic risk, although some aspects of financial systems are considered in the analysis.

The *emerging* dimension of systemic risks is shaped by the view to the future. A multitude of trends, developments, driving forces and obstacles are at work which will affect in important ways the nature of risks and the context in which they are managed. Thus, factors influencing the evolution of hazards and the vulnerability of systems over the next ten to fifteen years (and in some cases longer) are of great significance. But so too are factors that might modify the propagation of damage, or that affect the likely responses of institutions and the perceptions of the public.

Finally, the sheer complexity of today's world requires a holistic approach to the subject of emerging systemic risks, which must endeavour to capture not only the interdependencies and interactions among the hazards, various systems and forces influencing the overall context of risk management, but also the increasingly important international dimensions.

2. The growing impact of emerging systemic risks

According to various measures, the severity of major risks seems to have increased throughout the world in recent decades.[2] One indication of this is the trend in the frequency or in the magnitude of certain major disasters.

First, the observed number of natural disasters, including floods, storms and droughts, has risen dramatically since the beginning of the 1960s (Figure 1). In the past decade, such disasters have resulted annually in some 79 000 fatalities, with 200 million people affected (Figure 3).[3]

Fortunately, these human costs are by and large smaller than in the first part of the century, thanks to progress in health care, urbanisation and construction, and emergency services. Progress, however, has been much more limited in developing countries than in developed countries, so that victims of natural disasters are nowadays concentrated in the former. In financial terms, on the other hand, damage has grown exponentially (Figure 5), and is concentrated in developed countries (especially if insured damage is considered). Hurricane Andrew, which hit the United States and the Bahamas in August 1992, caused 38 fatalities and economic losses close to USD 30 billion in 2000 prices. By comparison, Tropical Cyclone Gorky killed 138 000 people in Bangladesh in April 1991 but had only a modest impact in terms of insured losses.[4]

Secondly, recorded technological disasters such as explosions, fires, and transportation accidents have also risen rapidly since the beginning of the 1970s (Figure 2). Their human cost has increased in parallel, mostly in developing countries (Figure 4). During the 1990s, they caused on average 8 000 fatalities and affected 67 000 people per year. In financial terms, their cost has been exceptionally high in the past two decades, but remains erratic (Figure 6).

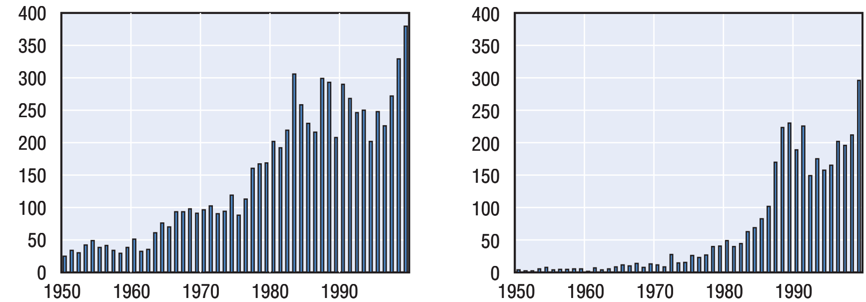
According to these measures, recorded technological accidents are generally relatively small events with a limited scope in both space and time with respect to their human and economic impacts, especially when compared to health or natural disasters. This does not exclude, however, the occasional occurrence of very large accidents, such as the 1987 ferry collision in the Philippines (4 375 victims), the 1984 chemical factory accident in Bhopal, India (3 000 victims), the 1986 nuclear reactor meltdown in Chernobyl (31 immediate victims, 135 000 reported affected, USD 2.8 billion in economic losses), or the 1988 Piper Alpha oil platform explosion in the United Kingdom (167 victims, insured losses close to USD 3 billion in 2000 prices).

Thirdly, disasters related to health have gained ground. The "Health For All 2000" accord signed in 1978 by the member states of the United Nations predicted that by the end of the century, infectious diseases would no longer pose a significant threat to human beings, even in the poorest countries. Today, it appears that the long-term trend of progress in the control and eradication of infectious diseases that fuelled this optimism has been reversed. This results from a number of factors, including the spread of drug-resistant microbes, the emergence of new infections with devastating effects

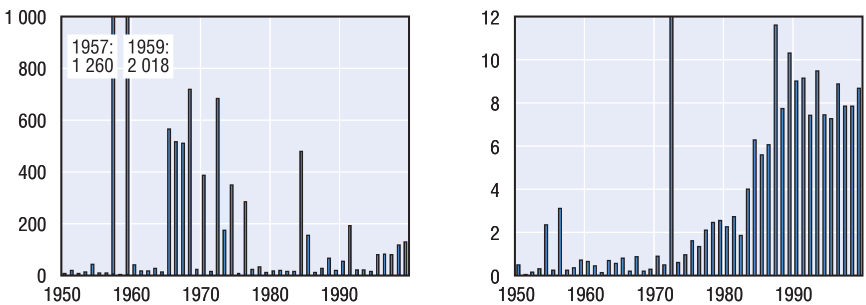
Figures 1 to 6. **Long-term trends in disasters**

Natural disasters | **Technological disasters**

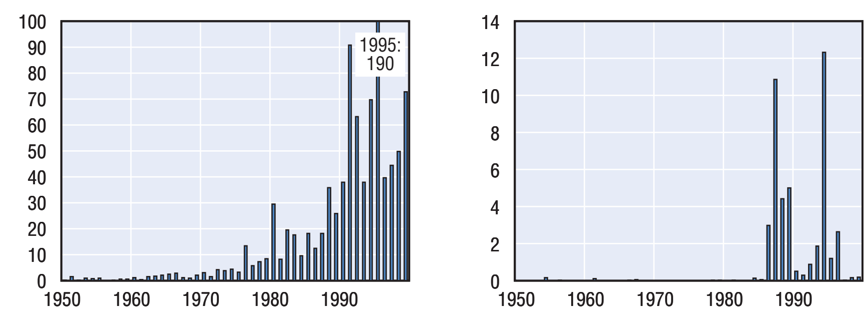
Figures 1 and 2. **Number of events**



Figures 3 and 4. **Fatalities (in thousands)**



Figures 5 and 6. **Financial costs (in billions of US dollars)**



Source: The OFDA-CRED International Disaster Database. An event is considered a disaster when one of the following conditions is fulfilled: 10 people are reported killed; 100 people are reported affected; international assistance is officially requested; a state of emergency is declared. Natural disasters include some health disasters such as famines. Due to the difficulties in collecting reliable and comparable data, all figures have to be used with caution. Financial costs include both direct costs and, when available, indirect costs (*e.g.* economic or environmental losses induced), in current dollars. They are not adjusted for inflation and currency fluctuations.

in some parts of the world, adverse socioeconomic factors such as the rise of megacities with poor sanitary conditions, and the rapid increase in cross-border movements of people and merchandise.

Around 13 million people die every year from infectious diseases, primarily measles, pneumonia, cholera, AIDS, tuberculosis and malaria.[5] Moreover, infectious diseases have been found to contribute to the development of many other diseases, notably cancers. It is estimated, for instance, that 6% of the world population is at risk of liver cancer caused by chronic infectious hepatitis B and C (WHO, 1999). The majority of victims of infectious diseases originate from developing countries of Africa and Asia, where chronic health crises have become one of the principal obstacles to development. But OECD countries are also, albeit to a much lesser extent, subject to risks of pandemics, to the growing resistance of microbes, and to food-borne diseases. For instance, tuberculosis and diphtheria, which were almost eradicated from Europe, have bounced back in recent years. In the United States, influenza epidemics kill between 10 000 and 40 000 people in an average year.

Admittedly, these figures have to be taken with extreme caution. First, the observed increases are in part due to better methods and tools of observation. Whether, for instance, natural disasters are actually becoming more frequent remains a highly controversial issue. Second, as emphasised later (Chapter 2), measuring the economic consequences of a disaster is a highly difficult task – especially when few data are available, which is often the case in least developed countries. Moreover, relative figures are probably more appropriate for measuring the economic impact of disasters. For example, the July 1997 floods in Poland appear as a medium-size disaster if their absolute cost is considered (close to USD 3 billion), but a major one when this figure is compared to the size of the economy (3% of the country's gross domestic product). Third, insured loss figures, although increasingly consistent, cannot be used as reliable indicators of economic loss. Indeed, insurance coverage is extremely uneven among countries, sectors and risks. For instance, infrastructure, which often represents a large share of physical damage due to a disaster, is not always insured. Floods represent a third of the number of natural catastrophes throughout the world, and are responsible for half of all fatalities and a third of economic losses due to natural catastrophes. Yet they account for only a small share of insured losses (10%) as the market for flood insurance hardly exists in many parts of the world.

On the other hand, many major risks that seem on the rise, such as those related to the release of pollutants, are not included in those figures. The notion of disasters itself does not capture various risks with diffuse effects in both space and time, such as those related to the use of asbestos. Finally, such figures overlook one major aspect of risk in modern societies: the psychological impact, which in itself can have important "tangible" consequences. In any case, it can be safely stated that the impact of risks on our societies has been increasing in recent decades.

This trend will in all likelihood continue in the coming years. It is estimated, for instance, that the already considerable economic losses due to Hurricane Andrew could have been fivefold had its course been slightly different. Based on the experience of the Kobe earthquake in 1995, insurance companies consider that a large earthquake in Greater Tokyo would entail damage of between USD 1 000 billion and USD 3 000 billion, equivalent to 25%-75% of Japan's GDP. In 1999, the "Geneva Mandate" closing the International Decade for Natural Disaster Reduction promoted by the United Nations stated that "the world is increasingly being threatened by large scale disasters triggered by hazards, which will have long-term negative social, economic, and environmental consequences on our societies and hamper our capacity to ensure sustainable development (...)" (IDNDR International Programme Forum, 1999).

An important feature of modern disasters is their rapidly far-reaching consequences in space and time. In today's highly interdependent and networked world, even a local event can have substantial repercussions in distant regions of the world through its impact on technological or financial networks, trade flows, migration, public health or the environment. To quote a major reinsurance company, "the possible extent of damage caused by extreme natural catastrophes in one of the large metropolises and industrial centres of the world has already attained a level that can result in the collapse of the economic system of entire countries and may be even capable of affecting financial markets throughout the world" (Munich Re, 2000).

Our societies are therefore increasingly subject to major risks, in particular with regard to their ability to fulfil vital functions such as the provision of health services, transport, energy, food and water supplies, information and communication, safety and security. The next section seeks to identify the driving forces – demographic, environmental, technological, economic and social – that are modifying the nature of risks and the context in which they are evolving.

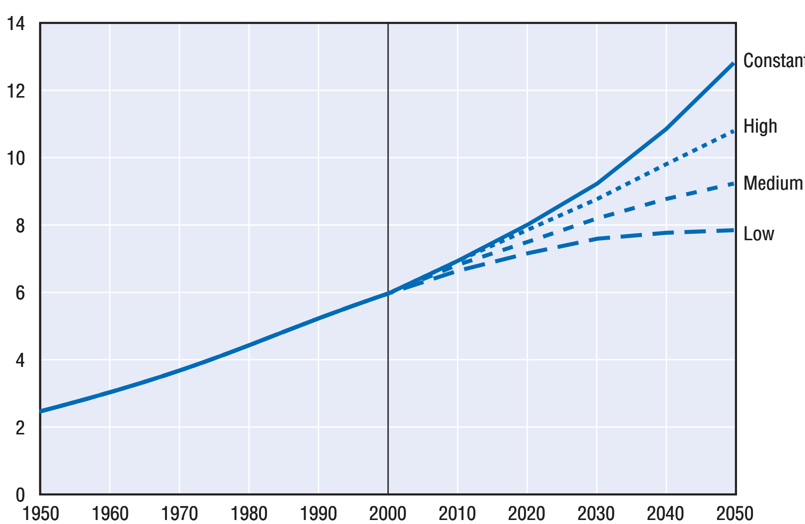
3. Expected changes in the risk landscape

Four categories of driving forces can be expected to influence the nature of risks and the way they are handled in our societies in the future: demographic, environmental, technological and socioeconomic. These are trends, already discernible today, that may modify usual hazards or create new ones, change the way disasters and accidents spread and generate reactions, or amplify the vulnerability of vital systems in OECD societies and economies in the future. Risks and their evolution might be directly influenced by a single driving force, such as urbanisation. Or, they might be subject to the interaction of several driving forces compounding their effects, as might happen with climate change, wealth inequalities and improved transport facilities.

Demography

According to the latest demographic projections of the United Nations Population Division, world population is expected to increase by more than 3 billion in the next half-century, reaching 9.3 billion in 2050 (see Figure 7 and UN, 2001a). Virtually all of this increase will take place in developing countries, particularly in Africa (+1.2 billion) and Asia (+1.8 billion). In these regions, population growth, in addition to growth in income per capita, will raise the needs for food, water, energy and land (both residential and agricultural). Energy consumption, for instance, is expected to rise by almost 350% by 2050 in developing countries (Brown, Gardner and Halweil, 1998). Consumption of coal in developing countries might be close to 2 billion toe (tons oil equivalent) in 2020, or 59% of the world total, while corresponding figures in 1997 were 1 billion toe and 46% (International Energy Agency, 2000). Even with persisting problems of food security, the total use of cereals in developing countries is

Figure 7. **Estimated and projected population of the world (in billions) by projection variant, 1950-2050**



Source: United Nations (2001).

expected to reach 1 500 million tons in 2010, compared to 970 at the beginning of the 1990s (De Haen, Alexandratos and Bruinsma, 1998).

Such scale effects will very probably aggravate various environmental stresses (OECD, 1999a), which will in turn affect numerous future risks. The extension of the human habitat and activities can induce new health-related risks. Agricultural development as well as the building of dams and irrigation systems, for instance, has facilitated the spread of diseases such as malaria and schistosomiasis in recent years. It has also been shown that agricultural or residential encroachments in forested areas increase the risk of human contact with unknown microbes (Wolfe *et alia,* 2001).

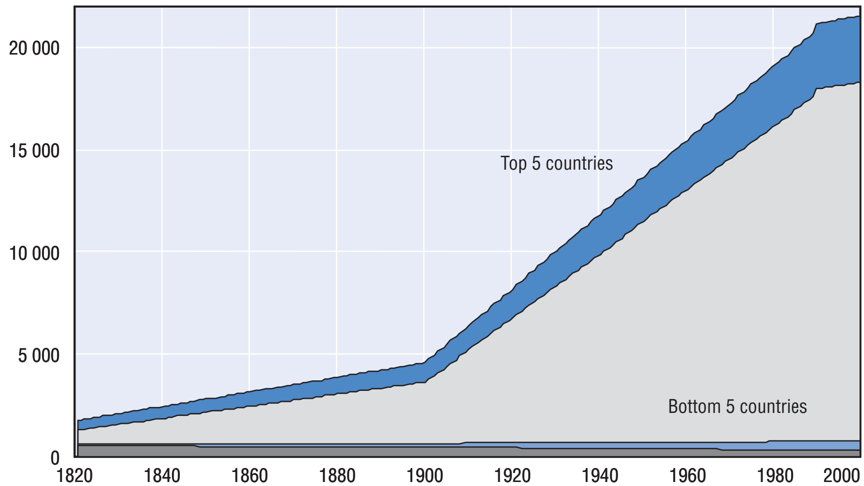
In addition, three dominant aspects of ongoing global demographic evolutions are expected to have a substantial influence on risks: ageing, migration and urbanisation.

The share of the population aged above 60 is expected to reach 33% in 2050 in developed countries, compared to 19% in 2000 (UN, 2001a). Similar evolutions are taking place in some developing countries – in particular China, with corresponding figures of 30% in 2050 and 10% today. Ageing does not necessarily entail a worsening of the population's health status. Its impact on the number of old people with severe disabilities, for instance, could to a large extent be offset by the current downward trend in disability rates, if it continues (Jacobzone, Cambois and Robine, 2000). But ageing will probably induce a gradual *shift* in risks, increasing some and reducing others. The vulnerability of populations to various infectious diseases in particular might be aggravated. For instance, the potential consequences of a worldwide influenza pandemic, considered very likely by epidemiologists in the medium to long term (Gensheimer *et alia,* 1999), is likely to become more disastrous in regions where the share of the elderly is growing.

Mass migration has increased dramatically in the world during recent years. In the year 1996 alone, the figure reached 50 million people, or 1% of the world population. Migrants are often particularly exposed to infectious diseases. In addition, large population movements confront health systems, even in OECD countries, with new and untraceable risks of disease, as is already becoming increasingly evident. And the trend is not expected to reverse in coming years.

Ageing, for instance, is one of the factors that might contribute to larger migratory flows in the world. Under a "baseline" scenario concerning retirement behaviour, labour force growth will decelerate in almost all OECD countries, and even become negative in most European countries and Japan during the next twenty years (OECD, 1998a). Although it seems highly unlikely that such a decrease will have to be entirely offset by a positive migratory balance, the possibility exists that tight labour markets in OECD countries,

Figure 8. **Trends in inequality in real GDP per head among countries***



* In 1990 US dollars. Inequality between countries is measured by the income range of the five countries at the top and bottom of the income league in selected years.

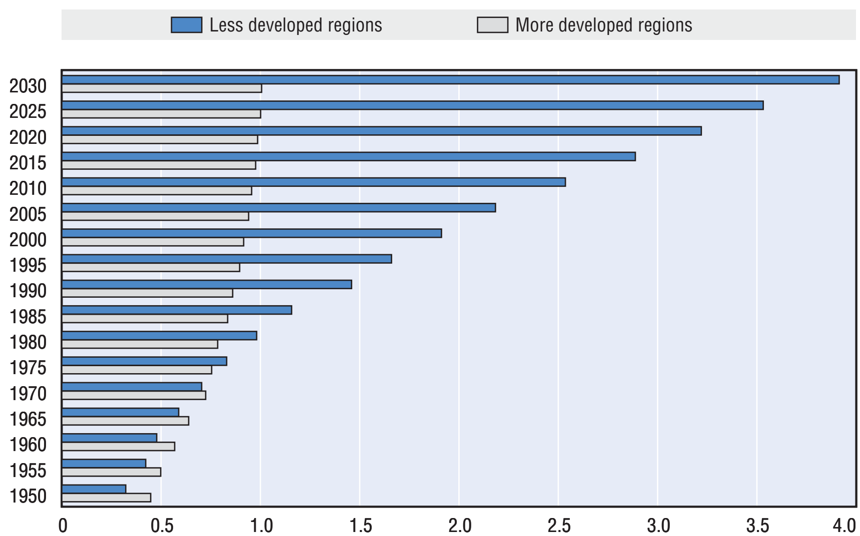
Source: Maddison (1995), OECD (2001d).

combined with persistent gaps in labour income and living standards *vis-à-vis* developing countries, may increasingly encourage clandestine migration and work.

In addition to economic and political factors, another cause of migration is expected to develop rapidly: environmental problems. Rising sea levels, subsiding coastal land, droughts and water scarcity, *inter alia,* are expected to trigger massive population movements. By some estimates, the impact of global warming on coastal regions alone will provoke the displacement of 30 million people in China, 30 million in India, 15 million in Bangladesh, and 14 million in Egypt by 2050 (Myers, 1993). There is a risk that such movements may happen principally in the wake of natural disasters, in emergency conditions, with important repercussions for public health. Particularly inside less developed countries, migratory flows are likely to continue supporting the development of large urban areas, exacerbating health, sanitary, construction, and location problems.

A variety of other factors are set to reinforce urbanisation trends around the world. With globalisation favouring the development of economic clusters, "region cities" are emerging as players in the global economy (Spector and Theys, 1999). Modern communication and information technologies might facilitate such concentrations by allowing more interactions among people (McGee, 1999). In many developing countries, the growth of manufacturing and service sectors will encourage urbanisation (Theys, 1999). For some experts, urban areas might count for two-thirds of the world population and occupy twice their current surface of land by the 2020s (Jones and Kandel, 1992). In developing countries, it is estimated that 95% of population growth in the next 25 years will occur in urban areas, compared to 40% between 1950 and 1975 (Figure 9). The number of "million-plus" cities in these countries is thus expected to increase rapidly. In many cases, the development of such centres is likely to overwhelm local capacities of urban planning, investment in infrastructures, and supply of basic health and sanitary services.

Figure 9. **Urban population (in billions) in developed and in developing countries**



Source: United Nations (1999).

The concentration of people, activities and assets in large urban clusters in itself increases their exposure to adverse events such as natural and technological hazards and infectious diseases. Of course, if these areas have not been built in accordance with adequate construction norms, do not offer satisfactory sanitary conditions, contain large pockets of poverty, and are particularly exposed to specific hazards (*e.g.* floods or landslides) – as is already the case in numerous growing cities – the increase in vulnerability is even higher. Already today, 40 of the 50 fastest-growing urban centres in the world are located in earthquake-endangered areas. It is estimated that by the middle of the century, one-third of the world population will live in seismically or volcanically active zones (Randall, Turcotte and Klein, 1996).

Environment

The planet's environment is undergoing major changes that are increasingly considered to be related – at least partly – to unsustainable human activities during the past fifty years.

The atmosphere's gas composition has been significantly modified by anthropogenic gas emissions. An increase in the atmospheric concentration of carbon dioxide (CO_2) started at the beginning of the industrial era after having been stable for at least seven centuries, and has continuously accelerated since. It is nowadays close to 370 parts per million, compared to 280 in the pre-industrial period. Tropical deforestation is currently estimated to exceed 130 000 km^2 a year as a result of the expansion of land devoted to agriculture and habitat. The forested area of developing countries has decreased by 10% since 1980, and is expected to lose a further 10% by 2020 (OECD, 2001a). In agricultural areas, soil fertility and biological diversity have been reduced by the intensification of cultures and, in certain cases, by the uniformisation of crops.[6] As a consequence of population pressures and contamination (primarily chemical pollution due to agriculture), global freshwater resources per capita have fallen from 17 000 m^3 in 1950 to 7 300 m^3 in 1995 (OECD, 2001a). Freshwater ecosystems have been considerably altered by overexploitation, pollution, habitat degradation and sometimes the introduction of alien species, resulting in the extinction or decline of some 20% of all fish species. In the middle of the 1990s, it was estimated that 5 200 species of animals and 34 000 species of plants were threatened globally (Secretariat of the Convention on Biological Diversity, 2000). For some experts, the world might even be on the eve of a major extinction event, with the loss of a quarter to a half of all existing species by 2100 (Powledge, 1998).

Such a loss of biological diversity would considerably alter the landscape of natural hazards in the long term. Diversity expands the number of potential interactions inside a system and therefore offers, on average, higher stability and resilience. Biological diversity therefore determines the ability of ecosystems to resist and to adapt when a disturbance occurs. In general, its reduction is closely followed by an increase in the incidence of diseases and in the presence of invasive species, as witnessed in coastal ecosystems today. Moreover, biodiversity provides numerous goods and services to humanity, including genetic material used in the design of new medicines or in crop and livestock breeding. The loss of biodiversity therefore diminishes our ability to respond to the future challenges posed by natural hazards.

Climate change today constitutes another highly preoccupying environmental trend for the future of risks. According to the latest evaluations, the average temperature at the surface of the planet has increased by 0.6 °C during the twentieth century. Such a rise in global temperature is very large by historical standards, making the 1990s the warmest decade of the past millennium in the northern hemisphere. As a consequence of warming, the global extent of snow cover has receded by some 10% since the end of the 1960s, the global average sea level has risen by 0.1 to 0.2 meters in the course of the century, and precipitation has increased in the higher latitudes of the northern hemisphere while it has decreased in sub-tropical regions. Climatic phenomena such as heavy rains in parts of the northern hemisphere, warm episodes of the El Niño Southern Oscillation over the tropics, and droughts in some regions of Asia and Africa have gained in intensity and frequency (Intergovernmental Panel on Climate Change, 2001).

Most experts now agree that the global warming observed in the 20th century is in large part due to human activities, primarily through the emission of greenhouse gases. The future of global warming is therefore to a large extent linked to the future path of greenhouse gas emissions, which in turn is influenced by population growth, economic development, technology – notably in the transportation and energy sectors, agriculture and land use – and policies at work in different parts of the world aimed at curbing emissions. Various assumptions concerning each of these variables generate a wide range of emission scenarios (Intergovernmental Panel on Climate Change, 2000). Concerning CO_2 emissions, for instance, recent projections vary between 4 and 30 GtC (gigatonnes of carbon) per year in 2100, compared to 7 GtC today, depending notably on environmental policy and technological change assumptions. In no scenario, however, do global CO_2 emissions decrease before 2040.

In any case, due to the long lead times involved in climatic changes, global warming is expected to continue during the 21st century. According to the scenarios reported by the IPCC, CO_2 concentration in the atmosphere will be 45% above the present level in 2100 under the most favourable set of hypotheses, and 260% above it in the worst case. Once other sources of warming and feedback from ocean and land, notably deforestation, are included (albeit with a high level of uncertainty), the global average temperature is expected to increase by 1.4 to 5.8 °C, causing more intense precipitation and a rise of 0.1 to 0.9 meters in the sea level.

Clearly, some regions will suffer hardship under such swings in climatic conditions, while others may benefit. Desertification and water shortages, in particular, might be aggravated. At the same time, however, a marginal change in the average of a distribution suffices to induce a very substantial increase in the probability of extreme events. The modest rise in average temperatures during the twentieth century has, for instance, gone hand in hand with an increase in total precipitation of 10 to 40% over Northern Europe and 10% over the United States. It is therefore considered likely that climatic accidents such as droughts, heavy rainfall, floods and tropical cyclones will become more frequent in the coming decades in many parts of the world. For example, torrential rainfalls and milder winters might substantially aggravate the risk of flood waves throughout the European continent.

Finally, the change in temperature and humidity will probably have important consequences for health as the panorama of disease changes in some regions of the world. Warmer climate may reduce some illnesses but amplify others. And as the survival conditions of a variety of infection vectors (*e.g.* mosquitoes) and other disease-causing organisms (*e.g.* salmonella) are modified, the incidence of both endemic and imported diseases is likely to increase. In some parts of Europe and of the United States, malaria or leishmaniasis, for instance, could develop, and food-borne diseases might become more frequent (Longstreth, 1999, Kovats *et alia,* 1999).

Technology

Technological change creates new risks, diminishes others, and in turn can be motivated by the need to cope with risks. It is often associated with increases in efficiency, and therefore lower use of resources for a given output level. However, the resulting decoupling between economic growth and environmental damage will probably be too limited to offset the rise in ecological pressures in the coming decades (OECD, 2001a).

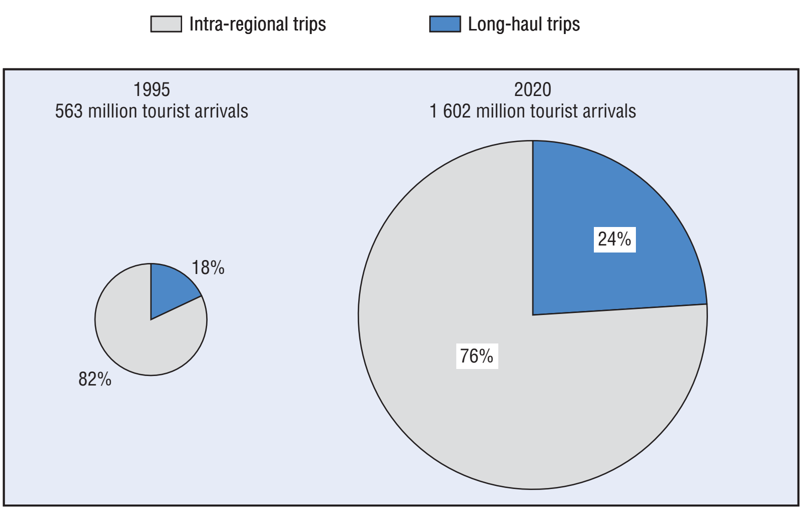
Among the numerous promises and perils of emerging technologies (OECD, 1998b), three aspects constitute the principal focus of this section: connectedness, the speed and persuasiveness of technological change, and a possible change in the *nature* of technological risks.

Connectedness has been described as a distinctive feature of modern societies, linked to the central role of networks (Castells, 1996). Information, communication, space and transport technologies have developed possibilities of exchange between people – no matter how distant – to an extent that few imagined only twenty years ago. According to some, this evolution is likely to intensify, due in particular to progress in the semiconductor industry (Gallaire, 1998) and, at a later stage, in molecular electronics. Facilitated by regulatory change and the development of transport, trade and information systems, many activities nowadays result from the interaction of a variety of actors inside networks, often on a global scale.

From the point of view of risks, connectedness makes individuals and organisations accessible over distance, both for the better and the worse. On the positive side, victims of disasters are easier to reach, and emergency rescues can be organised more efficiently. Monitoring and warning systems can be developed thanks to satellites and wireless communications. Capacities for gathering and processing information on natural processes and hazards as well as diseases increase dramatically, helping to improve our understanding of risks.[7]

On the negative side, connectedness multiplies the channels through which accidents, diseases or malevolent actions can propagate. Natural disasters at one side of the planet can have substantial economic and financial impacts at the other. Epidemics spread more rapidly and more widely due to the intensification of international travel and trade and the development of tourism (Figure 10).[8] Every day, computer systems and internal networks are submitted to electronic attacks originating from sources that are usually unidentified. Although in each of these cases damage is highly unlikely to spread to all parts of the network (thanks in particular to improvements in design), it might nonetheless affect some critical nodes, with devastating second-round effects.

Figure 10. **International tourist arrivals worldwide**



Source: World Tourism Organisation (1999).

Biotechnology, robotics, xenotransplantations and nanotechnology are emerging rapidly as the most promising technologies of the 21st century. Some could help tame the risk-aggravating forces described above. For example, the possible contributions of biotechnology to the development of sustainable agriculture adapted to the local conditions of each region would help break the link between growth in nutritional needs and environmental stresses. Biotechnology could also make considerable inroads into infectious diseases, for instance by improving vaccines and drugs and by increasing our knowledge of drug-resistant pathogens (Arber and Brauchbar, 1998).

But these technologies also have radically new aspects compared to previous technologies. They have benefited from rapid progress in scientific knowledge and applications which are expected to continue apace. Many of them are pervasive: they are already incorporated in virtually all sectors of economic activity and present in many aspects of our daily lives – or will be in the coming years. Many vital systems and critical infrastructures in our societies rely upon them. As a result, organisations and regulations are submitted to intense pressures for change. Risk assessment and management procedures in particular have to be continuously adapted to changing technological structures.

Furthermore, next-generation technologies often entail a modification of living matter. Combined with the continued increase in capacities for computing, transmitting and storing information, they represent a potential for transforming humans and their environment that probably has no precedent. At the same time, they are capable of interacting far more closely than ever before with the living environment. They are often self-replicating, or might be relatively easy to access once their development is completed (low fixed costs, common raw materials, etc.). Therefore, they might diffuse easily, and trigger long-term evolutions that are extremely difficult to predict.

Uncontrolled release of genetically modified organisms, the subject of an intense debate during past years, is among the first examples of the risk issues induced by new technologies. It has been established that the possibility of interactions between GMOs and wild plant species, as well as that of unintended effects on the human metabolism, need to be carefully examined (OECD, 2000). Some experts consider, however, that the long-term risks of such evolutions are especially difficult to assess, in particular because the results are to a large extent dependent on local conditions (Rissler and Mellon, 1996).

According to some controversial analyses, many next-generation technologies might generate unforeseeable risks with irreversible (or extremely costly) consequences, while their potential uses will be virtually impossible to control (Joy, 2000).

Socioeconomic structures

The last decades of the 20th century have seen radical changes in all OECD and numerous other countries towards economic openness, social diversity, mass education, and both a reduction in and a transformation of the state's role. The hoped-for increase in economic flexibility and efficiency might in many cases improve these countries' responsiveness to risks and performance in risk management. In some respects, however, these evolutions might raise new issues.

Globalisation and competitive pressures, together with technological change, have in some industries encouraged the search for efficiency through larger scale and a high degree of concentration. These efforts can currently be observed in production units (*e.g.* super-aeroplanes and gigantic dam projects), market concentration (mergers and acquisitions leading to oligopolies), and geographical concentration (*e.g.* industrial clusters). In addition to competition issues, concentration can imply higher vulnerability to shocks, in particular to accidents and natural hazards. At given levels of safety and total capacity, anticipated damage due to an accident is higher for a supertanker than for several separate tankers. In the same vein, interconnected information networks will be more vulnerable to a dysfunctioning or an electronic virus if they all use the same software. On the other hand, when concentration is lower, for instance by decision of regulatory authorities or as a result of technological change, risks recede.

In order to avoid an aggravation of risk, levels of security have to be dramatically improved when concentration increases. At the same time, corporations as well as regions are engaged in fierce economic competition, and might favour short-term productivity and profitability objectives at the expense of long-term safety and reliability (Rasmussen, 1997).

Another aspect of socioeconomic change under globalisation is the persistence of widespread poverty and income discrepancies between countries, regions and people. Entrenched poverty, quite apart from aggravating sanitary and health problems for large swathes of the population,[9] can also fuel social and political tensions (*e.g.* drugs, violence) in the regions concerned. Coupled with the possibility of a widening income and wealth gap between OECD countries and developing countries following the emergence of the knowledge economy, developments might spill over into the international arena in the form of larger uncontrolled migratory flows and criminal activities.

Risk management is also radically modified by shifts in the regulation capacities of our societies. The role of governments in the economy is changing, as evidenced by the gradual dismantling of state-owned monopolies. Public issues related to risks nowadays involve a variety of actors, including corporations, representatives of civil society, non-governmental organisations, experts, various levels of administrations and international institutions. The allocation of responsibilities among these actors, however, will be clearly defined only after a transition period. Meanwhile, novel risk situations might be met with excessive inertia or inappropriate institutional responses, as illustrated by the blood transfusion and the BSE crises in several European countries.

At the same time, the central role of information in modern society and the actions of those involved often exacerbate the perception of risks by the public and press decision makers to engage in immediate action. The role of the media in particular has been highlighted in the process of shaping collective responses to risks (Horlick-Jones, 1995). Decision makers are therefore confronted with a variety of time scales, from the long periods needed to understand new risks, to define new responsibilities and to build new regulations, to the short-term imperatives of communication and action.

Some propositions and caveats

The driving forces described in the preceding sections are expected to modify substantially the context of risk management and, in some cases, to increase the systemic risks our societies will face in the coming decades. That statement needs to be accompanied by a major caveat and two general implications. First, there is no deterministic trend in the rise of major risks in modern society; second, risks will increasingly have to be considered from a forward-looking standpoint; third, there are a number of interactions and feedbacks between these forces that can only be appreciated through a holistic approach to risk management.

Firstly, solutions to cope with risk-aggravating trends exist and will continue do so. They will partly result from adaptation and self-organisation: people, corporations, and communities will respond to new risk conditions in innovative ways, in particular through the use of insurance and financial instruments. Moreover, technological solutions could be found, some of which, as mentioned above, are already on the horizon: biotechnology applications in food and health, less-polluting forms of energy (OECD, 1999b), among others. Finally, solutions might be reached thanks to appropriate regulatory policies. The ongoing international efforts aimed at creating the tools to cope with global warming and to promote biological diversity are the first contours of such policies. However, solutions will take time to emerge and to produce effects. Meanwhile, the driving forces continue to play. The IPCC's projections concerning the greenhouse effect show that, even under the most favourable set of technological, behavioural and policy assumptions, global warming will probably continue until the end of this century.

Secondly, risk management must be based less on historical records, and more on methods anticipating changes in the nature of risks, relating to frequency, intensity, vulnerability, repercussions, etc. At the local level in particular, it may frequently be of crucial importance that people be informed and prepared for risks that did not even exist in the past.

Thirdly, in many cases, the driving forces interact with and reinforce each other. To give an example, in the absence of adequate economic structures and basic services (housing, water and sanitation, health), population movements often induce environmental stresses that in turn aggravate disasters, which disorganise further the supply of basic services and increase migratory flows. This type of chain reaction often produces the most tragic disasters, such as the December 1999 floods that killed 30 000 people in Venezuela (International Federation of Red Cross and Red Crescent Societies, 2000). Risk management and the scientific disciplines it relies upon (climatology, epidemiology, etc.) therefore need to integrate the often complex nonlinear dynamics of the various forces at play into a holistic approach to risks (Martens, 1999).

A possible starting point for such a holistic, forward-looking approach is to identify and analyse the cross-cutting critical issues that could increasingly challenge risk management in the coming years as a result of the driving forces described above. The next section briefly reviews a set of such issues.

4. The future of risk management: five critical issues

On the basis of the foregoing discussion, this section considers five key issues for the future: the heightened mobility of people, merchandise, technology and information, and increasing complexity of systems inside which risks are considered and managed; the rising scale and concentration of human settlements, activities or assets; the speed and scope of changes in risk conditions, and the uncertainty that results; shifting responsibilities for handling risks among public and private actors; and societal change and the perception of risks. As discussed in the following chapters, these issues are likely to affect every element of risk management in the years ahead.

Issue 1: Heightened mobility and increasing complexity

As the mobility of people, goods, services, technology and information rises, and as connectedness develops, so does the complexity of risks. Here, complexity is understood as the number of potential interactions that might influence the occurence and the consequences of a given hazard. Production processes are an example: production increasingly relies upon trade, income and investment flows, and sharing of knowledge throughout continents and sometimes the world. As a consequence, the number of events that can affect and disrupt the process has soared.

At the same time, we become more aware of the complexity of the world. One example of this is the long-term consequences of human activities for the environment, which can be out of proportion in relation to short-term, immediately measurable impacts. There could be a link between man-induced climate change and weather-related natural disasters. Genetically modified organisms could have long-term effects on microbial resistance. Chemical pollution could have a cumulative impact. All these links fall into the category of (hypothetical) risks that involve long-term interactions with the environment.

The approach to risk management needs to be adapted accordingly. Attention has to be less focused on the occurrence and direct consequences of a hazard, and be more geared toward indirect cause-effect relationships, diffusion, and long-term effects. One issue of particular relevance for emerging risks is that of propagation of hazards – how, for instance, to fight against the spread of diseases in a context of increased mobility, both nationally and internationally. A critical point here is to identify and protect critical nodes.

In that respect, the notion of systems is particularly fruitful. It emphasises the transmission mechanisms through which an initial disturbance amplifies, spreads inside or even beyond given boundaries, interacts with other disturbances, and ultimately alters the functioning of a process. The system in question thus includes the various components of an "accident": the causative event, repercussions, and final consequences.

The analysis of safety within complex systems (see Methodology Box 1) provides a remarkably pertinent framework for addressing major risks. Methods of risk assessment and management in complex systems have been successfully adapted to a variety of fields in the past (see for instance Health and Safety Executive, 1999). The same kind of approach has been used in the past by social science researchers to understand how society amplifies or attenuates risks.

In the following chapters, future challenges facing risk management are analysed from such a "systems" standpoint. The issue involves, for instance, the study of mechanisms to control propagation (either existing or proposed, *e.g.* in Europe after the BSE crisis) and improve safety during transportation (*e.g.* of chemicals, oil, radioactive waste). It covers the whole question of dissemination of powerful technological tools (nuclear, biological, computational capacities) equipping a large number of persons/organisations with a significant potential to do harm. It also highlights the crucial importance of being able to react to new risks as rapidly as possible and in close co-ordination with other countries.

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Methodology Box 1. **The safety approach to risks in complex systems**

Modern analysis of risks has been in large part elaborated in the context of systems. Systems are subject to accidents, in other words to unexpected events affecting their current or future functioning. Risk, then, is the potential for negative consequences of an accident. Perrow (1984) has produced an influential analysis of accidents inside systems. He underlines that the evaluation of the consequences of an accident is often limited to short-term losses, while long-term consequences that are admittedly much harder to estimate can be considerable as well.

An accident often results from the coincidence of two or several failings, each of which had been anticipated by the designers and operators of the system but which together were totally unexpected. The probability of such a conjunction increases dramatically as the system gets more complex. Uncertainty is often high in complex systems: as checking all possible connections would require huge resources, a multitude of them remain unknown. It is only when a failure interacts with another (apparently independent) failure that the connection becomes observable. It is then too late to circumscribe the accident. Lack of prior knowledge of interactions inside the system can even lead operators to misinterpret a signal and to initiate a "corrective" action that will actually worsen the situation. In Perrow's view, therefore, accidents in complex systems are extremely difficult to predict, and in a way "embedded" in the system.

The normal process inside a system can be either linear, with each part having only one task, or complex, with multi-task components. Naturally, the more complex the processes inside a system are, the more complex the system itself will be. However, even linear processes can experience "abnormal" complex interactions due to the proximity between various components, to the exchange of information between them, or to the exposure of seemingly independent components to the same environment ("common cause"). An external shock can affect both a process and the response procedures inside a system at the same time (*e.g.* restoration of the electricity network in France after the 1999 storms was substantially delayed by the simultaneous breakdown of transport networks). Nearly no system, therefore, can be safely considered as simple or linear: most systems comprise to some extent the potential for complex interactions. Risk analysis inside a system therefore has to take into account at least some features of complexity (Rasmussen, 1994).

Methods of risk assessment and management adapted to complex systems were developed initially for airplanes, soon after for nuclear reactors, and then for other hazardous activities.* Accidents here are both very rare and

Methodology Box 1. **The safety approach to risks in complex systems** *(cont.)*

unacceptable. Therefore, past accidents provide little empirical evidence, and the aim of assessment is not to predict accidents but to identify what subsystems/components are critical to safety in general.

In nuclear reactors, risk assessment is often based on failure mode and effect analysis. A first step consists in identifying all the ways in which the system's functioning can be altered, and finding all the possible chains of events (involving material or men) that could lead to such failure modes. Elementary failure probabilities are then estimated thanks to large collections of data, and quantification methods are used to evaluate the probability of combinations of failures. In order to minimise the possibility of an unexpected interaction, the system is usually described from several different perspectives. Rules of risk management, such as quantitative safety goals, are derived.

* See Rechard (1999) for a historical overview and, for instance, Farmer's seminal paper regarding safety assessment in the nuclear industry (Farmer, 1967).

Issue 2: Rising scale and concentration of human settlements, activities and assets

Urbanisation, rapid population growth in some parts of the world, large-scale projects and production units, reduced bio-diversity and other forms of concentration are all factors increasing the possibility of truly major disasters in the future. Diversity helps risk sharing through time and space. Concentration, on the contrary, aggregates risks. Therefore, the present trends make it necessary to take better account of the consequences of concentration for the vulnerability of systems in the future, and to promote diversity through a range of policies. Critical infrastructures and supplies, in particular, will need to become better differentiated.

Surveillance, protection and resilience of systems also need to be enhanced to compensate for reduced diversity. To what extent might the simple diffusion and effective use of existing prevention techniques and practices help reduce vulnerabilities? What are the possibilites for such diffusion and use, for instance in the case of construction and sanitary norms in many developing countries?

The prospect of more frequent large-scale disasters also raises a series of post-disaster issues. Can the current organisation of emergency rescues in various parts of the world cope with such events? What might be its shortcomings? What are the financing challenges posed by large-scale disasters, notably regarding rescue services and reconstruction? To what extent might more frequent "100 billion dollar loss" events affect the insurance and reinsurance industries? Might there be a decrease in the coverage of some risks? Will the role of states as insurers of last resort need to evolve accordingly?

Issue 3: Speed and scope of changes in risk conditions, and the uncertainty that results

The underlying conditions of risk are changing. It can be expected that the probability of occurence of and potential damage caused by a variety of hazards will be substantially different twenty years from now. The frequency of storms, floods, droughts and bushfires in some parts of the world, the world map of infectious diseases, and the threat of terrorism are just a few examples.

If it is based exclusively on past experience and data, risk management might prove to have serious shortcomings. The traditional retrospective approach to the handling of risk needs to be complemented with a more prospective and pro-active approach. This entails closely monitoring the driving forces of change presented in this chapter, analysing their relationships with risks, adapting risk management strategies accordingly, and ensuring that those strategies remain as flexible as possible.

However, anticipating the evolution of risks is often hampered by limitations in scientific knowledge, in particular in cases where a complex process of change is under way (*e.g.* climate change) or a radically new technology is introduced (*e.g.* xenotransplantations, or genetically modified organisms). Risk policies therefore also need to manage greater uncertainty than in the past.

In response to scientific uncertainties and to the growing impact of risk issues in societies, the notion of precaution – which has existed for a long time in food and health regulations – has emerged in recent years as a major concept in risk management. However, there is much debate about its practical implementation and enforcement. The "precautionary principle" has become a central issue for international co-operation, both because of its usefulness in the protection of the "global commons", and because of its implications for trade issues (OECD, 2000).

Issue 4: Shifting responsibilities among public and private actors

Roles and responsibilities in the management of risks have changed. In all OECD countries, privatisation, regultory reform and societal change have considerably modified the role of the state in the management of risks, in terms of both scope and nature. Centralised, command-and-control approaches to risk management might become less efficient in the future.

However, new roles and responsibilities are not always clearly defined, and the resulting vacuum seems to have led to major risk management failures in areas as diverse as health services, food safety and transportation networks. The vast majority of technical accidents are found to be due to human failure, and judiciary cases against individuals "in charge" (operators, regulatory authorities, governmental supervisors) develop. Such a focus on individual and case-specific responsibilites in accidents can lead to organisational and structural factors being overlooked, thus heightening exposure to the risk of repeated accidents.

Finally, while a range of risks are emerging that are unmistakably global, the international co-ordination of risk management policies is at best in its infancy.

Successful risk management strategies in the future will therefore need to adapt their instruments to this new context: provide information and promote risk awareness; create sound and effective incentives; develop partnerships; clarify the legal frameworks and make adequate use of legal tools; co-ordinate national policies; and, when necessary, create international tools.

Issue 5: Societal change and the perception of risks

Many recent examples show that in modern societies, anticipation of and reactions to a hazard are often as important as that hazard's physical (or "objective") characteristics in determining the final human and economic consequences. Indirect damage caused by public reaction might be substantial, even when direct damage is not (Kunreuther and Slovic, 1999). It has been estimated that "stigmatisation" can generate a yield premium close to 15% in addition to the normal risk premium (Chalmers and Jackson, 1996). Lack of information on risks and extensive media coverage have been found to be two major channels of social amplification of risks (Burns *et alia*, 1990).

Handling risks in a fashion that is coherent with societal views and needs (see Methodology Box 2) is one of the most challenging aspects of the risk management process. How does the changing nature of risks (linked to new technologies, climate change, demographic patterns, etc.) affect the way society reacts to them, and hence the way in which they must be managed? How do changes in social and political patterns (in particular progress in democracy, decentralisation, increases in living standards) affect the way society views risks and the practice of risk management? How is it possible to identify in advance cases where deep societal concerns will need to be

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Methodology Box 2. **The perception of risks**

Over time, approaches to understanding societal reactions to risk have changed. People in their everyday lives often do not behave as if they rationally considered probabilities of occurrence of hazards and corresponding outcomes. The Allais paradox (Allais, 1953) shows that people overstate low probability outcomes. Various experiments have also established that appreciation of risk depends to a large extent on how choice is presented (the issue of "framing" – see Tversky and Kahneman, 1981). In the past, such results were generally considered to be mere signs of the "irrationality" of the public in situations involving risk.

Modern approaches, however, have become more refined. Numerous studies have shown that human behaviour is actually determined by a set of factors in addition to probabilities of occurrence and outcomes (Krimsky and Golding, 1992). For instance, people show a relative preference for situations where they can influence the outcome (the issue of "controllability", *e.g.* driving a car compared to taking the plane), and for risks taken voluntarily as opposed to involuntarily (*e.g.* smoking compared to ingesting small doses of toxic pollutants) (Slovic, 1987). The Ellsberg paradox (Ellsberg, 1961) shows that people have an aversion to ambiguous situations where they have to estimate personally the probabilities of occurrence. Indeed, risk problems in society are often related to situations of "non-knowledge", *i.e.* of scientific uncertainty, as recently illustrated by the BSE crisis in European countries (Tacke, 1999).

Society's attitudes toward risk are influenced by culture (Douglas and Wildavsky, 1983) and evolve through history. In Western countries, for instance, the understanding of losses due to risk, responsibilities in risk taking, and acceptability of risks have substantially changed during the past century (Ewald, 1996). At the beginning of the 20th century, losses nowadays attributable to risk appeared as the consequence of a fatality that individuals had to face in their everyday lives with prudence. With the progress of science (notably epidemiology), it appeared that losses were not necessarily a fatality, and, at the same time, that individual behavioural rules were sometimes quite unable to prevent them. Hence, during the course of the 20th century a wide range of risks (health, work injuries and disabilities, etc.) appeared as social issues. The question, then, was not so much who was responsible for losses, but how to share the financial burden of compensation across society. In most European countries, the mission of reducing risks and organising insurance schemes was then assigned to the Welfare State, before it was shifted at least partially to the private sector. More recently, attention in OECD societies has started to focus on a new class of collective risks that could be generated by human activities themselves, ranging from technological risks to global warming (Beck, 1986).

Methodology Box 2. **The perception of risks** *(cont.)*

Collective attitudes towards risk also seem sensitive to the degree of equity (*i.e.* aversion to cases where a risk taker reaps the gains related to the risk while the losses are borne by others or by society at large); the collective memory (Foundation for American Communication and National Sea Grant College Program, 1995); and the degree of trust in the source of risk and in institutions in charge of risk management (Slovic, 1993). Finally, the "social amplification of risks" framework has also emphasised the roles of, *inter alia,* the media and crisis management decisions in shaping the reactions of the public and thus determining indirect consequences that can be of crucial importance (Kasperson *et alia,* 1988). Information provided by experts and by regulatory authorities, and the conditions under which it is transmitted by the media, therefore appear as major determinants of social reactions to risks.

appropriately addressed? What are the most effective strategies for risk management and decision making in each case? How can risk be identified and confidence in an acceptable response be built? These are some of the questions this report addresses.

Notes

1. The vast bulk of existing literature on risks relates to specific sectors or areas of activity (*e.g.* health, the environment, nuclear, insurance). Not surprisingly therefore, usage and interpretations of terms such as "risk", "hazard", "vulnerability", tend to vary. This report, by contrast, cuts across a wide range of risks and activities. Consequently, the concepts and definitions developed here constitute an attempt to forge terminological ground for the study broadly acceptable to most experts, without striving to create a new consensual set of definitions – such as, for instance, the risk management vocabulary guidelines recently established by the ISO (International Organization for Standardization, 2002).
2. See also International Federation of Red Cross and Red Crescent Societies (1999 and 2000).
3. The figures relating to natural and technological disasters in this section are taken from the International Disaster Database jointly established by the USAID's Office of Foreign Disaster Assistance and the Centre of Research on the Epidemiology of Disasters (*www.cred.be/emdat/intro.html*). See the comments accompanying figures 1 to 6.
4. Swiss Re (2001), Munich Re (2000).
5. The latter five are either incurable or showing increasing resistance to available medicines.

6. For instance, when diversified traditional crops are replaced by a small number of high-yield varieties (Rissler and Mellon, 1996).
7. See, for instance, the Global Disasters Information Network (*www.gdin.org*).
8. Cases of malaria, for example, have been observed recently near the international airports at Geneva, Oslo, and Brussels. The cholera epidemic that hit Latin America at the beginning of the 1990s, with about 11 000 fatalities, originated from a ship carrying contaminated water from Asia.
9. For instance, malnutrition is an underlying factor behind a majority of child deaths by infectious diseases in the world (WHO, 1999). In 1997, an estimated 160 million children were malnourished.

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 EMERGING SYSTEMIC RISKS IN THE 21TH CENTURY – ISBN 92-64-19947-0 – © OECD 2003

ISBN 92-64-19947-0
Emerging Systemic Risks in the 21th Century
Risk Assessment

Chapter 2

Risk Assessment

Abstract. *This chapter focuses on risk assessment, a scientific process that aims to identify and evaluate each step in the evolution of a hazard, from its origins to its final consequences for the system in question. The process can take a variety of forms depending on the nature of the hazard, the system involved, and the context in which the risk evolves. In past decades a myriad of risk assessment procedures have been developed. Those that are briefly reviewed in this chapter include hazard and risk assessment for natural disasters, using tools ranging from statistical analysis to catastrophe models; toxicity assessment for hazardous substances, based on estimated dose-response relationships; and safety assessments for highly structured systems such as plants or aeroplanes.*

Executive Summary of Chapter 2

Risk assessment, as a scientific process, involves a number of trade-offs due to the complexity of risk. Risk models – like all models – necessarily simplify the universe. They often must consider a system isolated from its environment, and therefore may overlook underlying forces that influence hazard or exposure. In some cases they cannot give a full account of "real world" conditions, notably of the various pathways through which a hazard develops. They cannot consider all aspects of human behaviour. And, they cannot integrate all the indirect consequences of a hazard, which often result from unexpected linkages.

In the changing context of many major risks described in Chapter 1*, such limitations might gradually become crippling. Risk assessment therefore needs to rise to a number of challenges, in particular a more complete understanding of the determinants of hazards and vulnerability, and better evaluation of externalities and non-linear cause-effect relationships.*

Solutions are emerging from several directions. The concept of integrated risk assessment, for example, enhances convergence between the various disciplines that can help capture different aspects of a risk issue. Emphasis is gradually shifting to vulnerability, an understanding of how complex risks can affect various parts of a system. Moreover, determinants of human actions are being identified, ranging from organisational to cultural and social factors. Finally, improved methods of simulation and information gathering will probably lead to dramatic improvements in risk assessment.

However important such improvements may prove, there is now widespread recognition that risk assessment cannot simply aim at quantifiable scientific measurement, but should also integrate societal perception and amplification of risk. Many risk issues in the past years have highlighted a large gap between scientific assessment and society's perception of risk – which cannot be addressed through one-way communication from experts to the public.

If the scope of risk assessment is to be broadened to such dimensions, its processes will need to be "open, transparent and inclusive", bringing together all the stakeholders of a given risk issue. This will entail a considerably more complex decision process. For instance, many emerging risks are characterised by a large degree of scientific uncertainty and often generate (heated) controversy among experts, which makes it impossible to build a unique "objective" assessment. It will also be necessary *to identify uncertainties clearly, to separate facts from values held by stakeholders, and to come up with ways of coping with major uncertainties.*

The set of issues analysed in this chapter provides several cross-sectoral lessons for the future of risk assessment.

1. Introduction

In this chapter, risk assessment is considered from a dual perspective: as a scientific process aimed at measurement, and as the first step in making decisions on society's allocation of resources to reduce risks. The scientific function was first formalised by Otway (1973) and Kates (1976, cited by Rowe, 1977). The notion has been gradually refined to encompass several or all of the following steps (Rechard, 1999):

- Identify appropriate measures of risk.
- Define and characterise the system and agents acting on the system.
- Identify sources of hazards and, when needed, form scenarios (hazard assessment).
- Quantify the uncertainty of factors and parameters and evaluate the probability of scenarios.
- Evaluate the consequences by determining the pathway to exposure (exposure assessment) and the response to exposure (dose-response or sensitivity assessment).
- Combine the evaluated consequences and probabilities and compare them with risk limits.
- Evaluate the sensitivity of results to changes in parameters.
- Summarise the various elements of risk assessment to facilitate communication.

Each step of this process can vary in rank and importance from one risk area to another, and can also involve totally different methodologies.

In short, the aim of scientific risk assessment is to describe risk as accurately as possible and, when appropriate, to quantify it. The most common measure of risk is the expected value of the consequences of a hazard (*i.e.* the probability of occurrence of a hazard multiplied by the value of the consequences). This measure has the advantage of making risks easily quantifiable and comparable. However, as discussed later in this chapter, it can also overshadow important aspects of risk. Alternative representations are therefore increasingly used. For instance, in numerous risk areas where there is a large variety of possible outcomes, the entire probabilistic distribution of the consequences is considered instead of their average value. In other cases focusing on precaution, an "upper-bound" value is applied.

Diagrams relating the frequency of an event to its expected damage are often used to present the range of possible outcomes.

From the decision-making standpoint, risk assessment is followed by two additional steps (in some cases called risk evaluation): a risk reduction analysis, where the need to reduce risk and the various options for doing so and their costs are compared; and a risk management decision where, based on the analysis and other pertinent considerations (social, economic, political, etc.), an option is chosen.

In theory, rational decision making presupposes comparing in a consistent way the costs and benefits attached to each option available for risk management, and accordingly ranking and prioritising the various risks facing society. In practice, however, there are major difficulties. Some situations involve a great deal of uncertainty, so that long-term evolutions can hardly be identified. Furthermore, a multitude of "abstract" societal values are often involved, for example relative to the cost of life or the distribution of risk among the population. An important issue for the decision-making process is how these aspects can be handled in a consistent and democratic way.

Risk is a social construct as well as a physical reality, and the two aspects are intimately linked. For instance, the scientific assessment of risks can entail value considerations that need to be addressed in accordance with societal preferences, notably in the way assumptions are made and uncertainties are treated. At the same time, it is crucial to assess risks as objectively as possible. The optimal balance, therefore, might well be to assure a large degree of independence to scientific risk assessment with regard to policy matters, while at the same time organising exchanges of information between risk assessors, risk managers, representatives of stakeholders and the general public.

The object of this chapter is not to review assessment in the diverse risk areas in detail, or to evaluate strengths and limitations in each case. It rather consists in analysing challenges faced in most – if not all – risk areas because of changes in the risk landscape, and in identifying concepts and tools that might help meet those challenges. Section 2 analyses risk assessment from the scientific standpoint, while Section 3 focuses on the decision-making process. A set of cross-sectoral lessons is discussed in the final section.

2. The complexity of assessing risks scientifically

Methodologies for assessing risks differ widely from one area to the other. They might have recourse to numerous scientific disciplines, such as geology, climatology, nuclear science, toxicology, epidemiology, economics, or sociology. They can rely on laboratory experiment, scale models, computer simulations or statistical observation. Various approaches need to be combined each time in the manner most appropriate to the particular risk issue.

Whatever their specificities, one problem is common to all methods: providing a complete evaluation of risk is an extremely complex task, and is likely to become even more so in the coming years as the complexity of risks itself increases. This section presents several aspects of current risk assessment methods, reviews some of the major challenges they face, and identifies a set of tools and concepts that could help to cope with these challenges.

The present context

A brief review of four methodologies helps clarify the current state of things: assessment of natural disasters based on a combination of statistical analysis and modelling; assessment of risks related to hazardous substances, and the specific role of dose-response relationships; probabilistic safety assessment of complex engineered systems; and consequence assessment, based on methods of cost-benefit analysis.

Occurrence of a flood

Various tools are used to evaluate the probabilities of exceedance of a given waterway and the characteristics of a flood in terms of discharges, regions affected, depth of water, etc.

The first step is usually hydrological analysis based on statistical extrapolations of historical data. For a given waterway, exceedance probabilities and discharges are established according to frequencies observed in the past. It is estimated, for example, that the strongest discharge recorded over a century has a 1% chance of happening in any subsequent year. Risk management measures are taken in accordance with such probability estimates. Many flood insurance programmes, for instance, provide coverage and support mitigation measures only where the event occurs more than once a century.

Morphological analyses rank among the basic methods of assessment: land forms shaped by the waterflow are examined to delimit flood plains for common or major swellings. In the past years, however, modelling has proved a more reliable way of simulating the overflowing of rivers, reproducing swellings experienced in the past and anticipating those that might happen in the future. Scale models are sometimes used. Alternatively, mathematical models can be built on the principles of hydrodynamics; be estimated on the basis of past discharges and flooding; and then be used to simulate the consequences of a certain stream flow. “Catastrophe models” based on zonation have been developed in cases where pertinent historical data were not available, with the aim of evaluating the propagation of hazards and their direct consequences. These models are continuously refined; most of them consider a variety of physical states of the riverbed as well as the flood zone.

Still, models incorporating a large geographic scale cannot integrate many local topographical details. In certain environments, important aspects of real phenomena cannot yet be fully accounted for (such as discharges in urban areas, or sediment transport for mountain streams). Such limitations affect final model results; the margin of error or uncertainty will vary with the model's scope and the amount of data (*e.g.* topographical) used (see Case Study 1 and Ledoux, 2002).

Exposure to a hazardous substance

In this area, risk assessment considers substances, exposures and effects, combining elements of toxicology, environmental sciences and statistics.

The initial steps are usually to determine what kind of toxicity or illness – if any – is caused by the substance, and how the incidence of adverse effects evolves with exposure. The usual assumption is that exposure to a substance can have consequences for health ranging from beneficial to harmful, depending on the dose (with the exception of many carcinogenic agents). Thus, once a hazardous substance is identified, its health impacts are usually evaluated according to dose-response relationships built on empirically determined thresholds, such as the No Observed Effect Level (NOEL) or the Lowest Observed Effect Level (LOEL). For carcinogenic substances, response is generally assumed to increase proportionally to the dose absorbed at low levels of exposure (unless a threshold level is observed).

The process necessarily involves elements of uncertainty, including reliability of the test method, differences between laboratory animal species and humans, variability among humans, and longer-term impacts. To account for uncertainties affecting the value of a parameter, the common practice is to determine a conservative upper (or lower) bound for it. In some food safety regulations in the United States, for instance, a safety factor is applied between the No Observed Effect Level determined from animal study and the Allowable Daily Intake. It is obtained by combining two factors: one accounting for possible differences between humans and the animal species used for testing, and another reflecting variability between humans.

Such dose-response relations are the cornerstone of hazard assessment for most issues related to human health, from water contaminants and pesticides to radiation (see in particular Case Study 5 on food safety), but also for some aspects of ecological risk assessments. In order to produce a risk assessment, the outcomes of hazard assessment must further be combined with the results of an exposure assessment, determining the levels of possible exposure. In some cases, an exposure pathway assessment is also performed to explore through which media and in what proportions and time scales populations at risk might be exposed.

The results can be synthesised by hazard characterisation, which includes information on the kind of damage likely to arise, the severity of the adverse effects, the populations affected, the likelihood of exposure, the risk's ultimate magnitude (*i.e.* severity of effects adjusted for the likelihood of exposure) and, last but not least, uncertainties affecting the estimation (National Research Council, 1996).

Accidents in complex engineered systems

Beginning around the 1930s, technological developments were increasingly geared toward engineered systems where the human and/or economic losses due to an accident were extremely large: commercial aeroplanes, nuclear weapons, atomic energy, satellites, large-scale chemical facilities, etc. In such systems, safety could not be gradually improved by trial and error. Reliability analysis was therefore developed to describe how the various components of a system were linked, and how a failure could happen.

Modern safety assessment of complex systems originates from these techniques. A variety of hazard identification methods are employed, such as hazard and operability studies (Hazops) and failure mode and effect analysis. The latter method, FMEA, consists in identifying all the ways in which the system's functioning can be substantially altered, and finding all the possible chains of events that could lead to and result from such alterations. The resulting fault and event "trees" have probabilities attached to each mode. In practice, collecting all possible modes usually proves extremely difficult, so that those with a probability of occurrence below a certain level are excluded. In order to minimise the possibility of an unexpected interaction, the system is usually described from several different perspectives.

Safety assessment, which was elaborated mainly for analysis of nuclear power plants, is nowadays used in numerous sectors involving complex systems – other sources of energy, air and maritime transport, chemical plants and hazardous waste disposal.

A major feature of safety assessments is the focus on operator errors as a source of potential failures, through Human Reliability Analysis. Human actions and errors are classified and interactions critical for safety identified. Probabilities for such interactions are then estimated on the basis of historical records, laboratory data, data from training and virtual reality simulations, and expert judgement (OECD – NEA, 1998).

The advantage of risk assessment for theoretically well-structured systems is that only a limited number of interactions with the external environment need to be considered. Inside such "closed" systems, assessment can aim at identifying all possible chains of events leading to the realisation of a hazard, and all possible chains of consequences (even though those possibilities that are estimated too unlikely are excluded subsequently).

However, after the nuclear accidents of Three Mile Island (1981) and Chernobyl (1986), it was recognised that safety assessments focusing on the risk of nuclear core damage had to be gradually extended to the whole of nuclear installations, and to the external environment (respectively, Level II and Level III Safety Assessments). As the scope broadens to less "controllable" areas (such as impacts for people living near a nuclear power plant), failure mode and effect analysis is replaced by less complex methods of consequence assessment. Responses from the external environment, and in particular from people, are not formally integrated into such methods.

Assessment of human, environmental, and economic consequences

The impact of a hazard can be considered using various methods. That of consequence assessment, the most comprehensive, employs procedures similar to those of cost-benefit analysis, examined in detail in below. Application to the risk of nuclear accidents is described in Case Study 2. Such an approach has at least two major advantages. It produces a consistent summary of the various aspects of a risk impact that would otherwise be difficult to compare (*e.g.* damages with different time frames). Also, it has recourse to well-identified quantification methods, and thus limits the arbitrariness of risk decisions.

One major difficulty with consequence assessment stems from the fact that the same action can lead to substantially different measured effects, depending on the perspective. Relocation expenses after a disaster, for instance, are considered as cost from a compensation point of view, but not necessarily from a macroeconomic standpoint – where they might account for an increase in the value-added of hotel services. Thus this type of assessment can focus on short-term or long-term costs, and can adopt various perspectives depending on the goal assigned. It is crucial that cost/benefit analyses are used consistently in a clearly stated perspective (such as preparedness and management, compensation, estimation of external costs). Each perspective provides a distinct measure of the costs of a disaster; none can be considered as the "real" cost of the disaster.

It is crucial, therefore, that the scope of the analysis is kept compatible with the perspective adopted. In the case of nuclear accidents, for instance, the preparedness and management perspective emphasises the cost of countermeasures. The aim is to have short-term accident management policies (potassium iodide prophylaxis, sheltering and evacuation) and long-term protective measures (relocation, restrictions) conform to the "As Low As Reasonably Achievable" principle. However, as discussed in the next section, some indirect consequences of intervention are often overlooked in *ex ante* cost estimations. Indirect consequences of population movements, for instance, might be inflationary pressures in local housing markets. Agricultural restrictions might have considerable secondary effects as well (*e.g.* for the food processing industry).

The challenges

The risk landscape, as pointed out in Chapter 1, is changing, and tracking these changes is an essential task for risk assessment. This, however, calls for an understanding of extremely complex interactions, possibly going far beyond the traditional methods of assessment described above. A number of challenges have been identified by practitioners in the various areas of risk assessment.

First, estimation of the various components of risk (hazard, vulnerability, etc.) is often contingent on a number of specific upstream processes (*e.g.* demographic, economic or climatic processes). In other terms, risk assessment is based more on recorded observations of hazard occurrence and vulnerability than on a formal evaluation of the structural processes determining hazard and vulnerability. Secondly, in most risk areas, assessment methods are not yet able to reproduce "real-world" conditions. The chain of causal relations – from the occurrence of a hazard through to its final impact – is assumed to be quite simple; the focus is on hazards related to a single determined source, on single routes of exposure, and on direct consequences evaluated for single endpoints. Third, long-term consequences and externalities are usually overlooked. Finally, assessment methods often ignore the "human factor", or integrate simplistic and standardised human behaviour.

Assessing underlying forces

The gap that exists between the understanding of many fundamental processes influencing risk and practical assessment of risks is well illustrated by the case of natural disasters. Disasters such as floods and storms are one of the channels through which our planet releases the energy it receives from solar radiation and internal thermal activity. They are therefore elements of an extremely complex global process. At the same time, their precise manifestations and consequences depend on local conditions such as topography and the extent of human presence and activity. Thus, assessing the risks of natural disasters entails jointly analysing global and local processes. However, long-term forecasting of the local manifestations of global phenomena such as climate change has proved a particularly challenging task (see Case Study 1). Therefore, as explained in the previous section, assessment of hazards such as floods largely relies on the extrapolation of past data.

There is now a growing suspicion that climate change could cause a substantial increase in precipitation in many parts of the world in the coming years (International Panel on Climate Change, 2001). Many recent disasters have been interpreted as the initial manifestations of this change. The discharges observed in the rivers Oder, Nysa and Mozara in July 1997, which led to devastating floods killing over 100 people in central Europe, were all above levels expected once every thousand years. The ice storm that hit eastern Canada and the northeastern United States in January 1998 deposited 100 millimetres of freezing rain in Quebec; the once-a-century level is estimated at 15 millimetres.

Such examples cannot be individually attributed to climate change. However, if "exceptional" events were to become more frequent, they would entail dramatic revisions in risk assessment, from hazard to exposure and vulnerability assessment. The relation between a change in the frequency or intensity of hazards and the resulting change in damage can be far from linear: it is estimated, for instance, that a 10% increase in the speed of a 200 km/h wind can result in a 150% increase in the damage. Moreover, some experts consider that the increase in frequency and intensity of extreme events might well go hand in hand with a "clustering" of those events (McDonald, 1999). Many motions at work in the ocean-atmosphere systems have a time scale of several years, and exert persistent influences on weather events. Extreme events caused by such long-lasting factors would then be correlated, and could no longer be considered independent, as they currently are in insurance schemes.

Naturally, the assessment of hazards dependent on the climate would have to be revised accordingly, as would related risk management measures – including insurance. For land use planners, areas currently meant to be well protected from floods, either naturally or by containment installations, would become exposed.

The difficulty of integrating upstream evolutions in risk assessment models is not specific to climate change; it also concerns other long-term drivers such as land use and urbanisation, policies, or man-induced change in local ecosystems. Assessments thus rely on the implicit assumption that these underlying conditions are stationary.

At a time when forces described in the first chapter of the report – ranging from climate change or demographic trends to upcoming technologies – are expected to substantially transform the underlying conditions of risks, frequencies and relations observed in the past might be increasingly misleading. In such cases, risk assessment – if it is to determine the final consequences of ongoing structural changes – must combine traditional methods with more forward-looking approaches.

Accounting for "real-world" conditions

In most areas of health risk assessment, analysis of pathways going from the hazard source to the exposed endpoints, and of the various types of exposure, has remained limited. In addition, risks are often evaluated for single sources and, when needed, aggregated under the assumption that they can be added. Finally, impact assessment does not generally consider the long-term evolution of exposed populations or ecosystems in response to exposure. All in all, a number of potentially important interactions and feedback might be ignored by existing risk assessment methods (Environmental Protection Agency, 1997).

In the long term, factors such as accumulation of an agent in the environment, interactions among various substances and consequent changes in the biosphere might be important factors of risk. For instance, some chemical pollutants, including heavy metals and a number of pesticides, have been found to persist, and therefore accumulate, in the environment. They have the capacity to follow unexpected routes and reach unexpected endpoints, and possibly to interact with other substances. As a consequence, there are often two dimensions to the risks that they carry: one is related to the short-term local effects of their release, the other to the long-term regional (or global) effects of their cumulated level.

Endocrine disrupters are another group of hazardous substances that have highlighted many gaps in assessment methods. These chemicals have the ability to interact with the hormone systems of humans and animals and, in some cases, of harming their development and reproduction functions. While the precise mechanisms behind the disruptive action are still uncertain, there is a possibility that these chemicals involve highly unusual dose-response relations, interact in mixtures, and violate traditional assumptions such as cross-group predictivity. Assessment here would entail enhancing current test methods, developing novel toxicity and reproductive tests, and further researching disrupters' modes of action (OECD, 2002a).

Finally, biotechnology – which is based on modification of living material – raises a number of new questions linked to potential interactions between species inside an ecosystem. Genetically modified foods also raise a number of health risk assessment issues, notably concerning the effects of antibiotic-resistant genes and the introduction of unexpected alterations in nutrients.

Assessment of such potential interactions is expected to become even more complex with the next generation of GM foods, where new traits will often be created by inserting multiple genes, making any reference to "traditional" counterpart products more difficult (OECD, 2000a).

Integrating the human factor

Ultimately, human behaviour is in most cases a prevailing factor in risk. Taking adequate account of the human factor is essential not only for the accuracy of risk assessment, but also for the effectiveness of prevention (Chapter 3) and emergency management (Chapter 4). However, most current risk assessment models do not explicitly integrate the decisions of the agents involved – policy makers, corporations, operators, and lay people. Therefore, the factors influencing human choices remain outside the scope of these models. In particular, they cannot reflect the effects of changes in behaviour due to modified perceptions of risks, incentives or policies. This can lead to large biases in risk assessment, as indicated in several studies on human error in large industrial facilities.

It has been argued that safety instructions and rules are often inappropriate for the specific working conditions in complex industrial systems, so that they are seldom completely followed in practice. Even in the highly constrained operations of nuclear power plants, task instructions have been found to be frequently modified. Analysis of accidents in these settings have concluded that the root cause in some 80% of the cases is "human error", typically on the part of actors in the operational flow of events, (*e.g.* pilots, train drivers).

Such findings have led to comprehensive schemes for collecting accident and incident data. A recent review by Amalberti (cited by Rasmussen, 2001) of the highly elaborated system used in aviation concludes that its level of effectiveness has now reached a plateau and that further efforts tend to be counterproductive. A major reason for this is that organisational causes in which blame is placed on operative personnel are systematically under-represented in incident reporting: "investigators tend to consider that organisational causes are often difficult to relate to facts, often polemic, and rarely followed by changes, therefore give low priority to these causes in the final reports." As a result, "very few safety actions take place at the organisational level".

Other analyses of safety research – based on investigations of large-scale accidents, such as the Flixborough explosion (1974), the Zeebrugge car ferry accident (1987), the Clapham Junction train crash (1988), and the Chernobyl nuclear reactor meltdown (1986) – also show that accidents are often not due to chance combinations of technical failure and human error (Rasmussen, 2001).

Such analyses tend to confirm the impression that individual responsibilities tend to be over-emphasised, and systemic failures understated.

Accounting for indirect impacts

In all areas of risk, assessment of consequences hardly takes account of indirect effects and externalities. In particular, many immaterial costs, such as those resulting from a loss of image of the industry or region, are usually deemed "unquantifiable". It may be estimated that such effects are essentially short-term and/or of marginal magnitude. For instance, the loss of economic activity caused by a disruption in public utilities is usually not found to be persistent, and most economic models assume that following a recovery period the economy returns to its previous equilibrium path. Such assumptions can, however, be very vulnerable in specific conditions, and in tomorrow's networked societies those conditions are likely to become more frequent.

First, numerous recent examples show that indirect consequences can be far from negligible when the supply of a scarce resource is disrupted, when the service of a major infrastructure or ecological system is affected, or when intangible assets such as brand image and credibility are affected. Illustration Box 1, for instance, discusses the impact of severe earthquakes on the global economy, when activities are tightly linked. The bovine spongiform encephalopathy crisis in Europe also shows that indirect consequences of a hazard can even be considerably larger than its direct consequences.

Second, certain catastrophic events have a long-lasting effect on the equilibrium path of an economy, by affecting *inter alia* its human capital and infrastructures. Reconstruction delays, and therefore funding conditions, have been found to be a major determinant of such impacts. Transport infrastructures, for instance, are critical because they involve large investments, a long process of rebuilding, and possibly a lower priority than other vital systems such as power generation and distribution, telecommunications, water and hospitals. Studies on the impact of the 1964 great Alaska earthquake (Dacy and Kunreuther, 1969) and the 1995 Kobe earthquake (Chang, 2000) on maritime activity indicate that such delays can entail a persistent loss of activity in areas where competition originating outside the disaster area is strong. Therefore local and regional economic losses resulting from such events can be deep and persistent. Similarly, infectious diseases can have devastating long-run effects on the economy (see Case Study 3).

Evaluating the consequences of a hazard beyond direct measurable damage is a particularly challenging task – both from a theoretical point of view because of the variety of mechanisms and interactions at play, and empirically because of the vast quantities of data required. External effects

Illustration Box 1. **Earthquakes and networked supply chains in the computer industry**

A number of damaging earthquakes occurred during the 1990s, creating widespread disruption in vital parts of the economy, costing many lives, and having severe consequences for local and global infrastructures. Examples of such events took place in Kobe, Japan (1995), ChiChi, Chinese Taipei (1999), and Marmara, Turkey (1999). Developments in industrial production and infrastructure conditions now render it more probable that events of this type will have drastic consequences far outside of their immediate localities. Forty of the 50 fastest-growing cities in the world are located in earthquake zones; many of these are also industrial centres of some significance to the regional and world economy (Kleindorfer, 2000). The importance of paying close attention to the indirect effects of natural disasters, and to the systemic vulnerability that is created by strongly interconnected industrial and centralised networks, is best demonstrated by an example (Papadakis and Ziemba, 2000).

At 1:47 a.m. on 21 September 1999, an earthquake of magnitude 7.6 on the Richter scale struck ChiChi, Taiwan. Its epicentre was approximately 7 km northwest of ChiChi and 155 km from the capital Taipei. The duration was about 40 seconds, and tremors were felt throughout the entire island. The earthquake impacted severely on nearby high-tech facilities that produced computer memory chips, a crucial component in all computer-dependent systems. Since these facilities were a crucial part of the supply chain to the worldwide computer manufacturing industry, the earthquake and subsequent disruption in production had repercussions for major computer companies in Silicon Valley and elsewhere, and further downstream for suppliers of computer hardware in corporate and public infrastructures all over the world.

Even though production in ChiChi was only disrupted for a period of two weeks, there was a global shortage of memory chips. Uncertain of the earthquake's real impact, wholesalers started to hoard memory chips, increasing the spot price more than 4 to 5 times, which further exacerbated the global impact of the earthquake.

Still, the event in ChiChi may be characterised as a near-miss from the point of view of the global computer supply chain. An earthquake with its epicentre in Hsinchu, 110 km away from ChiChi, would have disrupted the global supply chain for several months rather than a few weeks. Hsinchu is the location of several different computer component production plants, and the Science Based Industrial Park – a site including 30 companies which provide a significant percentage of the world's semiconductor manufacturing

Illustration Box 1. **Earthquakes and networked supply chains in the computer industry** *(cont.)*

and silicon processing. Even though these companies were located so many kilometres from the epicentre, the earthquake still impacted on Hsinchu through a power failure when it disrupted a distant 345 kilovolt transmission tower and a switching station, making it impossible for the park to receive transmission from the south of Taiwan. The Science Park closed down for several days, which resulted in business interruption costs of up to USD 100 million per day – a figure that grew downstream in the computer supply chain.

Source: Hellstrom, 2001.

can be difficult to measure, especially when they involve a high level of expertise in various disciplines. For example, some of the important ecological functions of humid zones, such as retention and purification of water, which induce positive externalities for various activities ranging from agriculture to flood prevention, have been understood only recently. As a consequence, it has been estimated that a region such as La Bassée in France provided a service equivalent to a FFr 2 billion infrastructure investment in terms of flood prevention alone (Cohen de Lara and Dron, 1997). Many other ecosystems – in particular in developing countries – remain poorly understood, and therefore cannot be valued adequately.

Emerging responses

Integrated risk assessment

Many issues raised by major emerging systemic risks relate to the fact that a plurality of mechanisms are forming and developments are taking place, and these cannot be adequately analysed through isolated research disciplines. There is thus a need for a multidisciplinary approach in risk assessment. Several recent efforts aimed either at enhancing convergence between upstream and downstream disciplines, or at capturing the various aspects of a risk issue, have started to yield encouraging results.

For instance, progress in two directions has allowed flood forecasting with time horizons that go well beyond simple early warning systems. On the one hand, improved understanding of short-term climatic evolutions such as El Niño and La Niña has in recent years proved useful input for longer-term weather forecasts. As a result, reliable regional weather predictions have been produced several months to one year ahead. On the other hand, flood models using rainfall and runoff modelling have been developed to relate peak river flows to climatic and hydrological conditions. The coupling of the two tools has enabled flood probabilities to be estimated through simulations, and yielded flood risk assessment for near-future climates. For example, the April 1997 flooding along the Red River in North Dakota had been forecast three months in advance by the US National Weather Service (admittedly with a substantial degree of uncertainty regarding the height of the water crest) (National Research Council, 2001). With such time scales, risk prevention and mitigation measures other than emergency management can be elaborated.

Another example of integrated approaches is the emergence of seismic hazard assessment that introduces results from geological disciplines dealing with active faulting (neotectonics, paleoseismology, geomorphology, geodesy) to complement the historical and instrumental records of earthquakes. The major challenge here is to characterise earthquake cycles over recurrence times spanning from between 10 and 100 years in active tectonic areas to between 1 000 and 100 000 years in areas of slow crustal deformation. Such a method is promoted by the Global Seismic Hazard Assessment Program, launched in the framework of United Nations' Decade for Natural Disaster Reduction.

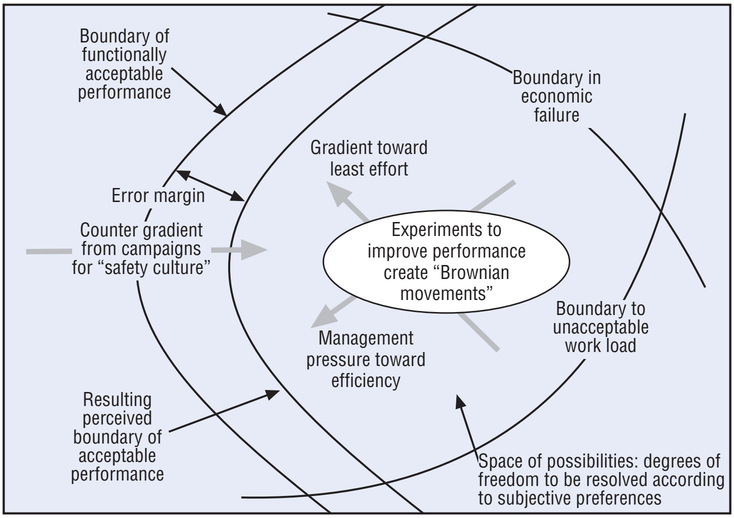
Some models have begun integrating well-known secondary effects (*e.g.* fires following natural disasters, disruption of economic activities or utilities). Other recent models comprise methods for estimating the macroeconomic magnitude of so-called "unquantifiable" impacts such as loss of attractiveness (Economic Commission for Latin-America and the Caribbean, 1997).

Vulnerability assessment

Improving our understanding of the factors influencing the vulnerability of specific entities or populations to hazards is one important step towards an integrated assessment of risks.

In the area of natural disasters, vulnerability assessment aims at determining those factors that make a given community or society (such as landless farmers in a specific area) more or less susceptible to hazards. Such factors can include density of population, physical vulnerability (*e.g.* weak soils) and poverty. Here, the focus shifts from the possible consequences of a hazard to the likely causes of damage. Such specific, scale-dependent assessment strategies may eventually be able to isolate an appropriate set of factors, analyse their interactions, and assess their overall influence on elements of vulnerability such as coping reserves and adaptive capacity (Clark *et alia*, 2000). One important aspect of vulnerability assessment is to identify the segments of a society that are more susceptible to damage. Doing so would lead to prevention strategies aimed at avoiding a dangerous combination of factors in each case.

Figure 1. **Modelling the safety performance of organisations**



Source: Rasmussen, 2001.

Likewise in the area of health-related risks, integrated assessment is characterised by a change of focus from hazard sources to endpoints. Conceptual models are developed to evaluate how a population or entity can respond to its various "stressors" following various environmental pathways (EPA, 1997). This should eventually allow a better assessment of complex risks with a multiplicity of sources, routes of exposures, or endpoints.

Organisational and external influences on human behaviour

Recent multidisciplinary research has highlighted the influence exerted by organisational or external factors on agents' response to risk situations and ultimately on vulnerability – in particular in the area of technological risks. Figure 1 gives an example of how an organisation can be modelled as a system subjected to forces that drive it more or less close to the boundaries of its normal functioning (notably in terms of safety).

Numerous organisational factors have been found to have an impact on safety performance, including: goals and strategies, management functions, resource allocation, human resource management and communication (OECD – NEA, 1999). External factors might be related to the political situation, the legal system, economic conditions, cultural aspects, regulatory frameworks, media reports and public opinion, etc.

Admittedly, the evaluation of such factors might prove difficult. However, characterising – even qualitatively – the major positive and negative contributors to safety performance could significantly improve the assessment and management of such systems. An additional step would be to identify leading indicators of the reliability of organisations in order to guide corrective measures.

Improved simulation methods and enlarged information bases

Simulation methods will certainly play an increasingly important role in risk assessment in the future. In recent years, they have brought together expertise from various disciplines, gradually integrated tools from complex system theory and from probability theory, and exploited increasingly detailed information bases.

Catastrophe models used for evaluating the impact of natural disasters have made considerable progress in recent years. Disasters are simulated and their effects are estimated through three modules: a hazard simulator, a vulnerability block, and a loss assessment module. Admittedly, these models are still subject to relatively large uncertainties, and require refinement (see Methodology Box 1). Nevertheless, they have the potential to analyse the precise local manifestations and impacts of large-scale phenomena thanks to detailed zonation.

Many recent models simulating the physical process at work in natural disasters have important non-linear features deriving from complex system theory. Such tools might help to improve not only our understanding of the process (*e.g.* fractal patterns), but also our ability to predict large events on the basis of leading signals (*e.g.* pattern recognition techniques, including neural networks) (Rundle, Turcotte, and Klein, 1995).

Probabilistic risk assessment methods have gradually emerged as necessary supplements to traditional deterministic studies, compared to which they provide a more balanced and realistic picture of a risk situation. Evaluation of probabilistic distributions for model parameters also helps to identify the various sources of uncertainty involved in the assessment. Ranges of fluctuations are determined for the parameters to reflect the degree of confidence attached to their estimated values. Uncertainties are then "propagated" through the assessment model, and their impact on endogenous variables and model's outcomes is estimated through sensitivity analysis procedures, such as the Monte Carlo simulation method.

In the context of the safety of nuclear power plants, where they have been largely developed, probabilistic assessments are used to identify the potential vulnerabilities of plants seen from a relative point of view (*i.e.* dominant contributors to risk) and not as bottom-line results. Criteria for backfitting decisions, they constitute analyses preceding deeper

Methodology Box 1. **Catastrophe modelling in earthquake loss estimation procedures**

Catastrophe modelling is used to estimate, at least partially, losses due to an earthquake. It usually follows a four-stage process:

- Based on seismic and tectonic information, a catalogue of earthquake events is generated. Each event comprises an epicentre located on a fault source, a moment magnitude associated with the rupture length of the fault, duration, an annual frequency, and a ground motion attenuation relationship. Microzonation allows a very detailed mapping of geological soil conditions, so as to identify the degree of amplification of ground motion during an earthquake.
- Exposure assessment is restricted to the building stock of the endangered area, which is classified according to its functions and architectural structure. For each class, building capacity curves and repair/replacement costs are estimated.
- The extent of damage to each building is then estimated according to probabilistic fragility curves.
- Finally, total casualties, displacements and economic losses are calculated for each event. To the extent that the catalogue of events is chosen in order to reflect as much as possible the local specificities of earthquake hazards, average and worst-case losses can be computed across the range of events. These are estimations of the average and the maximum damage that could result if an earthquake event was to occur, whatever the probability of such an occurrence.

Each assessment stage involves various sources of uncertainty: seismological data, building stock exposure data, vulnerability functions, and repair and replacement costs. The range of uncertainty resulting from each source can be estimated by varying the corresponding parameters (*e.g.* frequency of events, soil classification, etc.) and measuring the sensitivity of final results. Once all sources are included, sensitivity analysis often shows that earthquake loss estimation remains a highly uncertain process (Grossi, 2000).

investigations (OECD – NEA, 1992). They are gradually being applied to a wider range of risk areas – such as hazardous chemicals, where they can help gauge variability and uncertainty in toxicity and exposure (OECD, 2001). In many cases, however, reliable empirical methods to measure the variability of response to exposure among individuals are yet to be developed.

Finally, data availability and (especially as far as multinational simulations are concerned) compatibility are currently major impediments to a broader use of risk modelling instruments. More precise analysis calls for larger sets of data, higher cost and greater reliability. In this respect, geographical information systems are becoming a highly valuable tool that can provide a wealth of socioeconomic data on populations at risk, and help manage information at the various scales involved, from regional to local. Space technologies such as satellite imagery have begun to provide valuable means of observation and data collection (Illustration Box 2).

Illustration Box 2. **Remote sensing in rural Australia**

Satellite imagery can be used to monitor both the potential for and the extent of a range of natural disasters. Floods, droughts and bushfires are obvious examples. The usefulness of such data increases if thay can be integrated with other spatial data (*e.g.* roads, streams, digital elevation models, cadastral data).

To date, however, most successful uses of such data have been post-disaster. Analysis in hindsight can, of course, be very informative for scientists, policy makers and emergency managers – but it is of little immediate value to the people on the ground who are facing an impending disaster. For satellite imagery and integrated spatial data to be useful prior to – and more particularly, during – a disaster, they must be up to date, low cost, and easy to use.

Most current delivery systems of spatial data for local and remote users fail on all three criteria. Time lags, high costs and expensive/complex computer systems are invariably necessary and represent a critical impediment to the take-up of this important information source.

In 2000, the Australian Earth Data On-Line (AEDOL) project, with funding assistance from the International Decade for Natural Disaster Reduction, developed a prototype system that could overcome all of the above impediments for users who have nothing more than a standard computer and an Internet connection. The aim of the prototype was to provide an online automated service to deliver user-customisable remotely sensed imagery in the form of easy to read 3D visualisations. The prototype demonstrated near-real-time provision of satellite data at greatly reduced cost when compared with conventional supply channels.

Ready access to the viewer-friendly 3D visualisations of up-to-date satellite data presented an opportunity for active monitoring of impending disasters such as bushfires, droughts and extreme weather. Until now these opportunities have been largely restricted to organisations with specialist image-processing facilities and highly trained staff skilled in their use.

Illustration Box 2. **Remote sensing in rural Australia** *(cont.)*

By coupling WWW technologies to a state-of-the-art image-processing system using Advanced Very High Resolution Radiometer (AVHRR) imagery and other spatial data such as roads, rivers, towns, etc., users were provided with estimates of grassland curing, a vital input to calculations of grass fire danger. The data were provided within an hour of the satellite's transit over South East Australia.

The visualisations created by AEDOL permitted the spatial interrelationships between vegetation dryness and slope to be visualised and readily understood. The results showed how straightforward it could become to monitor local changes in grassland flammability during the annual build-up to a fire season (in response to rain and increasing temperatures). The results also provided graphic evidence of the changes in vegetation that occur within and between years in a rural area.

By providing not just access to the data and visualisations but also the capability for users to perform online interactive processing of the imagery, the system built for this project put great power into the hands of the end-users. It allowed them to customise the image products online without image-processing software or extensive expertise. They could also apply a consistent set of processing steps to each image so as to derive useful semi-quantitative assessment tools.

The project demonstrated the ability of state-of-the-art technology to fill a gap in the information available to rural communities. By providing access to the latest in value-added products the systems developed during the project could rapidly disseminate new techniques to support disaster risk management. The technologies developed in this project could also be easily adapted to similar problems in developing countries. Since no specialist hardware or software is needed at the user end, costs are kept very low. Moreover, the very limited training necessary for using the system proved tremendously helpful in disseminating these remote sensing technologies among non-specialist users and the general community.

Source: The Bob Hawke Prime Ministerial Centre.

3. Consistency and transparency in decision making

Once risk has been described as accurately as possible, the next step in risk management is to ask whether it should be reduced, and if so, to what level. Answering these questions consistently is a particularly challenging task, and making the best use of scientific knowledge to assess risk is a necessary but far from sufficient condition for it. It involves considering not only the possible consequences of risk-taking and their likelihood, but also the respective merits and limits of the various options for risk reduction, how costs and benefits would be distributed among individuals, whether societal values might be contradicted, and the state of knowledge and variety of standpoints regarding all these issues. In each case different stakeholders are concerned, and they should be informed of and possibly participate in the decision-making process. Society as a whole can be highly sensitive to risk management decisions, and here the media play an important role.

This section begins by examining risk management decision making in a context where the objectives of decision makers can be multiple, where opinions might differ, and where values need to be considered. Three principal challenges are then discussed: taking appropriate account of the degree of uncertainty involved; making decisions in an open and transparent way; and ensuring consistency. Various responses to these challenges are identified: a consensual approach to the use of precaution in risk management, informed use of cost-benefit and decision analysis tools, and a participative-deliberative approach to decision making.

The present situation

Reducing risks has costs as well as benefits. It necessitates human, capital and knowledge resources that come at a price.[1] It might also imply restricting the development of a technology or the exploitation of a resource, thus losing the benefits that would have resulted. Conversely, it limits the damage caused by a hazard and can produce positive externalities, such as economic growth and job creation in areas protected from hazards or in risk management activities.

In most cases, the costs of risk reduction become crippling and its benefits negligible below a certain level of risk. Therefore, it is generally not desirable to reduce a risk to zero (assuming that that would be possible), and various risk management concepts actually reflect the idea that reduction must not overpass certain limits. For instance, many regulations are based on the well-known notion of "As Low As Reasonably Achievable" or ALARA, which describes the "right" level of risk as the lowest achievable at reasonable cost.

Various tools and methods are used to determine the optimal level of risk.

A common practice is to measure risk by a single figure (such as the average annual number of fatalities or the total expected cost in monetary terms), and compare it to a benchmark. The risk to be assessed can be, for instance, compared to other, better-known risks.[2] The underlying argument is that a risk smaller (resp. larger) than risks which have been accepted (resp. rejected) in the past should be accepted (resp. rejected) as well. Quantitative risk acceptability criteria, such as thresholds under which a risk is deemed acceptable, are based on a similar reasoning. Such methods have major limits, notably due to the fact that benefits pertaining to risk-taking and options available for reducing risk are overlooked. They are therefore reliable only in circumstances where the risk context, including the costs and benefits of various courses of action, are known and factored into the equation. Otherwise, a familiar risk that would be expected to cost x, yield substantial benefits, and be costly to reduce might be equated to a poorly understood risk that would be expected to cost x equally, have negligible benefits and be easy to avoid.

The most consistent and complete tool commonly used to determine the optimal level of risk is cost and benefit analysis (CBA).[3] The principle of CBA is to fully quantify the choice problem faced by decision makers by attributing a value (usually monetary) to each possible current or future consequence. Values are supposed to measure changes in social welfare related to each consequence, and are weighted by the probability of occurrence of the specific consequence. They can involve the use of market prices, or alternatively valuation methods for non-marketable goods, such as shadow prices or willingness-to-pay. A discount factor reflecting the societal rate of time preference, is applied to future events. Model parameters, from probabilities of occurrence to dose-response relations, are based on available evidence and opinions of scientific experts. All factors relevant to the decision, whatever their nature, time frame or likelihood, can then be consistently aggregated in a single measure, such as the expected net present value or the benefit to cost ratio. The solution that provides the highest value for that measure is the one that can be expected to produce the largest social benefits.

The challenges

In practice, however, determining the right course of action with respect to emerging systemic risks is an extremely complex task. The scientific understanding of hazard, exposure and vulnerability can be limited. Opinions regarding risk and interests with respect to regulations can be contradictory. Differences in regulatory approaches or in society's perception of risks can lead to inconsistencies in the way various risks are handled.

Assessing uncertainties

Uncertainty is at the core of risk assessment. On the one hand, the aim is to explore and measure it; on the other, the process comprises its own uncertainties, which were sketched in Section 2 on scientific risk assessment.Various types of uncertainty are sometimes distinguished, according to their origin: measurement, statistics, modelling, etc. In general terms, uncertainty can relate to the values of parameters and exogenous variables determining the state of a well-identified system at a certain point in time; or, it can relate to knowledge of the process governing the system's evolution. What is in question in the latter case is not the value of the variables characterising the state of a system, but the very identification of those variables and their linkages.

In short, the first type of uncertainty affects the *accuracy* of risk assessment responses to questions: "What is the probability of occurrence of a hazard?" "At what levels does exposure become unsafe?" "What is the degree of vulnerability?" It is quite common to address such uncertainties with conservative measures. One practice, for instance, is to replace the estimated value of a parameter with an "upper bound" value (see the example of safety factors applied in the evaluation of admissible exposures to hazardous substances in Section 2).

The second type of uncertainty, however, affects the very *ability* of risk assessment to answer the above questions. Such uncertainties can be of particular importance for emerging systemic risks, where causal relations might be extremely complex and empirical knowledge as well as data availability related to past records is often modest. As discussed in the previous section, addressing this issue is possible in relatively close and well-structured systems, where the number of variables can be controlled and a large part if not all of their interactions explored. But it can become nearly impossible in open systems, such as those involving the living environment. For instance, assessing the risks attached to xenotransplantations, which necessitates among other things fully understanding the behaviour of organisms carried by the xenograft (transplanted organ or tissue, of animal origin) into the human body, including the possibility of mutations, is beyond reach with the current state of scientific knowledge.

The magnitude and nature of scientific uncertainties is naturally a crucial element of risk management decisions. It is therefore important that, in addition to the results of assessment, the underlying assumptions as well as the degree and nature of uncertainties are clearly exposed, and their implications for the accuracy and reliability of those results discussed (American Chemical Society, 1998, Skjong and Wentworth, 2001). A full assessment of these limitations represents in and of itself a great challenge in many risk areas.

Integrating uncertainties in risk management decision making can be straightforward in a number of circumstances. In some cases, for example, there is uncertainty regarding the "real" value of a parameter, but it can be estimated with a high level of confidence within a reasonably narrow interval. Sensitivity analyses then consist in choosing different values for the parameter inside that interval and measuring the resulting changes in the severity of risk, in the costs and benefits of various risk reduction strategies, etc. The risk management decision can then incorporate precautionary elements proportionate to the extent of uncertainty.

Risk management decisions become more problematic as the magnitude of uncertainty increases. Risk issues with large uncertainties and potentially serious consequences are often characterised by important scientific controversy (Godard, 1997). In some cases, such as risks related to terrorism (see Case Study 4), the possibility of a hazard can be foreseen, but the likelihood of its occurrence is very difficult to quantify.

In such circumstances, methods of evaluation such as cost-benefit analyses face serious limitations. CBA can be applied only in situations where a collection of scenarios can be assumed to represent the future and where a probability can be attributed to each. Some consequences of a hazard can be too uncertain to be accounted for *ex ante*. Sometimes extremely strong assumptions need to be made regarding the long-term evolution of variables like technology or policy (*e.g.* stability of policy options for the next 10 000 years in the case of nuclear waste depository sites).

CBA can also entail measuring complex external effects, *e.g.* to value the social capital or environmental assets. Promising methodologies have recently been developed to account for such externalities (see for instance OECD, forthcoming). However, as indicated in the previous section, often the fundamental knowledge of external effects itself remains limited. For instance, the value of irreplaceable environmental assets in the future depends upon complex evolutions in the biosphere that are impossible to anticipate with the current state of knowledge.

Even in presence of major uncertainties, the costs and benefits of various courses of action remain crucial elements of decision making. For instance, evaluation and simulation of extreme scenarios involving "speculative" causal relations can provide precious information, even if they cannot be integrated in a formal CBA. But, as scientific assessment and quantification of costs and benefits cannot alone determine the appropriate risk management decision, there is a need for articulating these in conjunction with other pertinent considerations in a coherent and efficient manner.

Ensuring consistency of risk management decisions

Numerous comparisons of risk management programmes have found differences of several orders of magnitude in the value of a life saved between countries or between risk areas, once the "objective" (or scientifically measured) level of risks is considered (see, for instance, Hood *et alia,* 2001). For the advocates of a "scientific" approach to risk management, such differences are signs that institutions in charge of prevention and the public at large have a biased perception of risks, leading to inefficiencies in risk management.

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However, proponents of a "social science" approach to risk management emphasise that decision tools such as CBA – and, for some, even scientific risk assessment itself – comprise elements of subjectivity, in particular in the hypotheses that are adopted and in the way uncertainties are addressed. They therefore represent a blending of science and judgement, with important psychological, social, cultural and political biases.

According to this view, for example, the fact that the value of a life saved is lower for some risks (*e.g.* car accidents) than for others (*e.g.* death from cancer) can be justified by psychological factors – such as controllability – that individuals consistently value and CBA overlooks (Tolley *et alia,* 1994). Attitudes towards risk also vary according to distributional aspects often ignored in CBA, where total costs and benefits are taken into account regardless of the number of individuals among whom they are shared. Finally, risk issues often incorporate value considerations that are difficult to include in usual decision tools such as CBA. For instance, valuing human life entails ethical questions that make the commonly used evaluation methods highly controversial (see Methodology Box 3).

The key notion, then, is not a so-called objective value of risk, but its acceptability by society: the perception of risks needs both to be understood and integrated in risk assessment. According to the "contextualist view", risk has therefore to be conceptualised as a game whose rules must be negotiated by the various stakeholders within the context of specific decision problems.

In societies that pay increasing attention to risks and are much more responsive to information flows than in the past, taking account of societal aspects of risk is a crucial element of risk management. Ignoring them and building risk management exclusively on scientific expertise can lead to citizens' mistrust in risk management institutions, and hence to overreactions to risk in the public. It is now increasingly recognised that a top-down, uniform approach to risk management cannot be appropriate in most cases because of the variety of risk situations and the value-laden nature of risk. At the same time, it has to be acknowledged that public reactions do not necessarily lead to efficient and equitable management of risks. Individuals indeed have access to limited information at reasonable cost, have limited mobility, and can be subject to heuristic failures (Breyer, 1997). In addition, whether values expressed by the public, such as dread, are systematically legitimate guides for collective choices is open to debate. In a context where society's overall resources available for risk management are limited, risk management decisions cannot be based solely on the public's perceptions.

To quote the Rapporteur's summary of the OECD Edinburgh Conference on the Scientific and Health Aspects of Genetically Modified Foods: "While there seems to be agreement that the social process of risk handling needs to

Methodology Box 3. **The challenge of valuing life in cost/benefit assessments**

The human capital approach and so-called subjective approaches are the two major methods of valuation for human life used in cost-benefit analysis.

In the human capital approach, the value of life is determined by the discounted sum of the individual's future earnings, taken as measures of his or her productivity. Therefore, the lives of different individuals have different values, and those of inactive people even have a zero value. Because of such limitations, it is considered that "this method can be useful for some regulatory activities (for instance, derivation of countermeasure criteria, comparison of options or measure of the impact of factors such as distance to the accident), as it allows a base comparison of objective quantifications of the value of a statistical life. It is recognised, however, that for other applications, such as for the evaluation of external costs of energy alternatives, the subjective valuation can offer more acceptable results" (OECD – NEA, 2000).

Subjective valuations, such as the willingness-to-pay approach, consist in estimating the cost of non-pecuniary effects by the amount a risk-adverse individual would pay to avoid their occurrence, based on survey techniques and revealed preferences studies. These methods also raise ethical questions. For instance, should evaluation be based on a situation where the individual has to buy his or her right to enjoy a normal degree of safety?

The two approaches are sometimes used in separate cost elements of the same assessment, which are added to obtain a measure of total cost. This, naturally, introduces a bias in cost valuation (Cohen de Lara and Dron, 1997). Furthermore, human capital valuations, as well as subjective valuations, need to integrate a risk premium, at least from the cost perspective of victims. Such a risk premium is related to the risk aversion of people, which is difficult to measure, in particular in the context of severe disasters.

be 'open, transparent and inclusive' and should clearly acknowledge scientific uncertainties and take into account the validity of social concerns, there is no consensus on how this should be done in practice" (OECD, 2000b).

Indeed, the challenge is to create a framework for clarifying the respective contributions of facts, value statements and uncertainties in risk issues. Decision tools need to have the flexibility to account for these diverse contributions, and to acknowledge that decision making has to aim not at a single objective (as assumed by traditional CBA), but at several objectives at the same time (such as making efficient use of available resources, addressing distributional aspects, and accounting for specific societal values).

Emerging responses

In sum, risk management decision making faces difficult challenges: On what basis to take decisions in the face of large uncertainties? How is it possible to ensure consistency while considering the multiple aspects of risk issues? How can facts be separated from values and stakeholders' standpoints integrated when appropriate? Responses to these challenge are beginning to emerge from three directions: common grounds for precaution; a enlarged framework of analysis of decision; and participative-deliberative processes of decision making.

Common grounds for precaution

When risk assessment entails too high a level of uncertainty to be a reliable guide for management decisions, one of two broad strategies of prevention can be adopted: either taking no preventive action and refining assessments gradually on the basis of experience (the so-called "learn then act" stance), or engaging conservative measures based on the possible magnitude of risk and improving assessments through fundamental research and controlled assays (the so-called "act then learn" stance). Illustration Box 3 shows how both strategies have been used in the past, and briefly discusses the costs involved.

The idea that in some cases the anticipative (act then learn) approach to risk management was preferable to the adaptive (learn then act) one is believed to have been first formalised in the 1970s, in the notion of *Vorsorgeprinzip*. This "forecaring principle" gradually became a cornerstone of German environmental policy, and was later referred to in various international fora as the precautionary principle. The precautionary principle figuring in the Rio Declaration of the 1992 United Nations Conference on Environment and Development states that: "Where there are threats of serious and irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

Precaution as a management principle has existed for a long time in a variety of areas, as illustrated by the use of safety factors in the estimation of dose-response relationships (see EPC, 2000, for a comparison between precautionary measures in the European Union and in the United States). However, a number of decisions referring to the precautionary principle have led to important disputes in regional and international jurisdictions in the past years, from the European Court of Justice (*e.g.* the German beer case) to the WTO (*e.g.* the beef hormone case).

The various international agreements referring directly or (more often) indirectly to a precautionary approach substantially differ when it comes to defining the conditions that precautionary measures must satisfy. What is

Illustration Box 3. **"Learn then act" and "act then learn" strategies of risk prevention**

Examples of "learn then act" and "act then learn" strategies are provided by the historical developments of radiation protection and experiments on the human genome, respectively.

Before the Second World War, protection from radiation was essentially concerned with occupational exposure to radium and X-rays. In the United States, the tolerance dose was then evaluated at 25 rem/year. In the late 1940s, scientific research took an interest in chronic exposure to low levels of radiation, notably near weapon production facilities. In 1948, as the hypothesis of potential harm from such exposure was formulated, the US regulatory body – the National Commission on Radiation Protection – decided to reduce the maximum permissible dose to 15 rem/year, and recommended limiting radiation doses to as low as reasonably achievable (ALARA) levels – a concept that subsequently became an important element of risk management policies. In 1959, based on new scientific evidence, the International Commission on Radiation Protection proposed to adopt a maximum occupational dose of 5 rem/year and a maximum dose for the public of 0.5 rem/year. Thus gradual improvements in scientific knowledge over the years showed that existing levels of prevention were less than sufficient, and led regulatory authorities to adapt the accepted levels of exposure.

At the beginning of 1970s, soon after the first recombinant DNA techniques were found, concerns of the scientific community regarding the potential harmful effects of such experiments for human health and the environment led them to engage in a series of voluntary moratoria (notably the 1974 international moratorium on certain classes of DNA experiments). At the 1975 international conference at Asilomar (California, USA), scientists decided to classify experiments according to the speculative risks they involved, and to determine an appropriate level of containment for each class of experiments. Based on the work done at Asilomar, several national health authorities, in particular the United States National Institute of Health, created official guidelines on recombinant experimentation. All the moratoria were observed without exception worldwide. The initial guidelines were extremely strict, but they also provided conditions for a selective easing in the future – and indeed were rapidly relaxed for successive classes of experiments. In 1976, Genentech Inc. used for the first time recombinant techniques to produce human insulin. Whether enough progress had been made in the assessment of consequences as restrictions were gradually lifted remains a controversial issue, but the Asilomar process is nevertheless certainly an example of best practices in terms of anticipative approaches to risk prevention and public trust building.

Illustration Box 3. **"Learn then act" and "act then learn" strategies of risk prevention** *(cont.)*

Both strategies have costs. Those of the "learn then act" stance are linked to potential damage (in the example above, the cost of cancers due to excessive exposure to radiations), to the extent that it would become more difficult to prevent as time goes by. In fact "learn then act" is costly only in those circumstances – if the costs of necessary prevention measures increase in time in the absence of immediate action. The "act then learn" stance involves opportunity costs, *i.e.* the loss of expected benefits (*e.g.* profits derived from the development of a potentially hazardous product or technology such as DNA recombinant techniques), in particular if risk finally appears acceptable, and in some cases sunk costs (*e.g.* bringing an alternative product or technology to the same stage of development).

meant precisely by "serious and irreversible damage", the need to assess such threats scientifically and the provisional nature of measures and their cost-effectiveness are among the major sources of divergence. As a consequence, there has been growing concern over the use of the precautionary principle by countries to increase their regulatory discretion, in opposition to trade agreements (OECD, 2000c). For instance, there is no agreement within the European Union on a precise definition, and member countries tend to criticise the work of the Community's scientific committees – which provide the basis for application of the principle – and rely on their own regulatory bodies (Scott and Vos, 2001).

However, as exemplified by the overruling of France's ban on UK beef from 1 January 2000 onwards by the European Court of Justice (judgement of the Court on Case C-1/00, dated 13 December 2001), a process of harmonisation might well be under way in the EU. Its cornerstone is the European Commission's February 2000 communication on the precautionary principle, which endeavours to set a common understanding of precaution. Conservative measures are required to be proportional to the threats, non-discriminatory and coherent, based on an analysis of costs and benefits, and flexible with regard to progress in scientific knowledge (Viney, 2001). In addition, the Commission seems to exclude the use of the principle as a substitute for the scientific exercise of risk assessment.

These clarifications tend to bring the Commission's interpretation of the principle closer to precautionary approaches advocated in multilateral fora (such as the World Trade Organisation's SPS agreement), but substantial differences remain (Majone, 2001). Further progress towards an international understanding of precaution-based strategies of risk management (and in particular their legal aspects) is warranted, and seems within reach.

An enlarged framework of analysis

During the past 30 years, scientists have developed techniques of decision analysis to help managers and policy makers make complex choices in the face of risk and uncertainty (for a presentation, see von Winterfeldt, 1992). The approach has several potential advantages over the conventional practices of risk analysis, stemming from a methodology grounded in specific framings or social contexts.

Decision analysis considers that there is no universally acceptable level of risk (Fischhoff, Lichtenstein, Slovic, Derby, & Keeney, 1981). Acceptable risk depends on the problem context and can only be understood in association with the management option that is best in that context. In other words it is decision-driven: as the management option changes, so too will the magnitude of the risk (*i.e.* probabilities, consequences, etc.) that is acceptable.

There are two immediate advantages. One is that process-based solutions to risk controversies are just as attractive as technically based solutions. If a lack of trust in plant management is an underlying reason for community opposition to a planned facility, then mitigation actions that address trust (*e.g.* forming locally based management groups with strong veto powers) may prove more effective in generating support than engineering-based solutions (*e.g.* reductions in emission levels). More generally, decision analysis systematically differentiates risk management measures according to the specificities of risk situations, which is certainly a major criterion of successful strategies today. The other immediate advantage is that some problems that have no answer under a risk analysis framework can here have straightforward answers. For example, the dilemma of selecting among the multiple expressions of mortality risks is answered by asking the stakeholders to choose what, from their point of view, is the "best" measure.

Decision analysis does at times integrate diverse impacts into a measure of costs and benefits. Analysts recognise, however, that much of the value of the method lies in the process of structuring the problem and eliciting relevant values, consequences, and probabilities (Keeney, 1982). In cases where participants think of the problem as disaggregated and multidimensional, the structuring process itself may be the principal contribution of the analysis, because it clarifies specific elements of the decision context that can in turn lead to novel risk management solutions.

The decision analysis framework allows the tools of modern risk analysis to be used as part of a broader context in which the emphasis is on creating a

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sound structure for decision making rather than addressing simply the concept of risk as a chance of loss.

The participative-deliberative approach

The limitations of risk science, the importance and difficulty of maintaining trust, and the subjective and contextual nature of the risk game point to the need for a new approach. Introducing more public participation into both risk assessment and risk decision making would make the process more democratic, improve the relevance and quality of technical analysis, and increase the legitimacy and public acceptance of the resulting decisions. Such an approach could also act as an early warning mechanism for future repercussions in the economic, social and political domains. Scholars and practitioners in Europe and North America have begun to lay the foundations for improved methods of public participation within deliberative decision processes that include negotiation, mediation, oversight committees and other forms of public involvement (reviewed in Renn *et alia*, 2002).

Development of better and more participatory procedures for risk management is still a work in progress. Probably the most detailed examination of the new openness to process-oriented solutions is that presented in the 1996 report of the US National Academy of Sciences (NRC, 1996). This report highlights the need to recognise all significant risk-related concerns.

The variety of persons who are concerned by risk decisions – public officials, experts in risk analysis, and interested and affected parties – may be concerned with a variety of possible harms or losses. Sometimes, risks to social, ethical, or ecological values are at least as important as risks to health and safety. The analysis serving as the basis for a risk characterisation must pay explicit attention to the breadth of the significant issues. This is often best done by involving the spectrum of decision participants directly in formulating the problem to be analysed.

The Academy of Sciences report also notes that improving risk characterisation requires attention to two discrete but linked processes: analysis and deliberation. Analysis uses rigorous methods developed by experts to arrive at answers to factual questions. Deliberation uses processes such as discussion, reflection and persuasion to communicate, raise and collectively consider issues, increase understanding, and arrive at substantive decisions. Deliberation frames analysis and analysis informs deliberation. Thus, risk characterisation is the output of a recursive process, not a linear one. Analysis brings new information into the process; deliberation brings new insights, questions, and problem formulations. The two build on each other. The analytic-deliberative process needs input from the spectrum of interested and affected parties.

Recognising interested and directly concerned citizens as legitimate partners in the exercise of risk assessment is no short-term panacea for the problems of risk management. But serious attention to participation and process issues may, in the long run, lead to more satisfying and successful management methods.

4. Cross-sectoral lessons

The case studies and illustrations described in the preceding sections provide some indication of the experience that has been acquired to date across a range of sectors in addressing new challenges to risk assessment. They also provide useful clues as to where progress in meeting these challenges has been most marked or is most promising. What is particularly interesting from the standpoint of this report is that some of the more successful approaches within particular sectors would seem to lend themselves to the assessment of emerging risks more generally. Six have been identified here.

Integrating the forward-looking perspective

Given the pace and scale of the changes unfolding in the 21st century, it is becoming essential to step up efforts to complement conventional techniques of risk assessment based predominantly on past observations with forward-looking approaches that give greater weight to likely future developments. As recent advances in the assessment of risks related to climate change, earthquakes and nuclear power plants show, a range of methods are becoming available that help to strengthen the future focus, be they simulations, probabilistic calculations, straightforward projections or scenarios.

Applying contextual thinking

It is self-evident that continual efforts need to be made to improve the knowledge base and reduce uncertainties. This in turn, however, requires recognition and acceptance of knowledge gaps and a determination not to exclude any possible underlying structural or contextual factor that may have a bearing on the issue at hand. The importance of openness is precisely the lesson that emerges from the progress made in risk assessment in such fields as nuclear power (with extensions of safety assessments to Levels II and III), climate research and infectious diseases. Its value can also be seen increasingly in the integration of cultural differences – local and international – into the assessment process.

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Implementing multidisciplinary approaches

The sheer complexity of modern systems and their environment renders the task of risk assessment increasingly difficult. Linear causality has become an unrealistic assumption and, as emphasised above, the context in which systemic risks occur and are managed plays an increasingly significant role. At all stages in the assessment process, elements need to be taken into account – economic, social, cultural, technological, scientific, geographical, environmental – which necessarily broaden the scope of exploration, investigation and evaluation. The risk assessment approaches that are most likely to meet with success in the future are those which effectively integrate and synchronise the various scientific disciplines pertinent to the broader, multifaceted nature of the risk in question.

Extending the knowledge base

What becomes clear from the above is that there are several dimensions to the knowledge base that are necessary for reducing uncertainty and improving risk assessment: knowledge specific to the field of the risk itself, knowledge imported from various related scientific disciplines, and knowledge of the wider context in which the risk is analysed. These requirements point to the need for enlarged databases, as well as the capacity to generate synergies from linking and/or sharing those databases both nationally and internationally. Significant advances are expected in the coming decades in information processing and in the gradual diffusion of "ubiquitous" computing, which should make a considerable contribution to expanding databases. Interfacing with and sharing information – within government administrations, between government and the private sector, among companies or between countries – is an area that holds great promise, but which is fraught with institutional obstacles as well as proprietorial and privacy problems.

Establishing common ground for assessment

Especially where risks have international implications, assessment is frequently complicated by discrepancies in risk perception and evaluation among different countries, due in large part to differences in culture and values. As the cases of hormones in meat and biofood demonstrate, methods and institutional mechanisms can be created which are conducive to multilateral dialogue and to the internationally consistent assessment of risks.

Involving the stakeholders

The subjective and contextual nature of risk, the acknowledged limitations of the "scientific" approach to it, and the need to build and maintain trust in relations between the various players, all point to the importance of introducing more public participation, not only into risk prevention and mitigation but also early on in the risk assessment phase. As this section of the report has outlined, substantial progress has been made – on the basis of experience in a number of risk areas – in laying the foundations for improved methods and mechanisms for involving society in the assessment process. A task for the future is to explore the possibilities for applying such foundations more broadly.

Notes

1. Which can be either their direct cost or their opportunity cost, in other words the remuneration that they would receive if they were allocated to other uses.
2. Risk comparisons considered here are therefore different from risk rankings based on a full assessment of costs and benefits, which can be used for instance when priorities have to be set.
3. One example is the Regulatory Right to Know Act recently emitted by the Congress of the United States, which mandates the Office of Management and Budget of the White House to systematically assess the regulatory activity of US federal agencies through a cost-benefit analysis.

Case Study 1 – Flooding

Assessing flood risk

A variety of different approaches are available to assess the flood hazard in any given territory (*e.g.* the extent of potential inundation).

One widespread approach is modelling. Here, the objective is to simulate the flow and overflow of rivers, in respect of flood levels that are either actual (observed in the past) or theoretical (never observed), and for differing physical states of the river bed and flood plain (past, present or future). Models can be physical or mathematical; the latter modelling has made enormous progress in recent years, in conjunction with the constantly expanding capacities of calculators. Mathematical models are first calibrated through calculations reproducing banks and the extent of inundation as caused by actual recorded flood events. They are then used to simulate the passage of other, generally greater flows to map out submerged areas and define the corresponding water levels.

There is no claim that such models offer an exact representation of an actual event. They have margins of error or uncertainty that vary with the scales used and the degree to which the various parameters (such as topography) needed to construct them are known. Comprehensive mathematical models cannot reflect local topography. Rainwater treatment systems are rarely factored in, and to model runoff patterns in urban areas is a delicate exercise. Modelling the movement of solid matter is also difficult, which makes the simulation of mountain torrents somewhat hit-and-miss. Statistical hydrological analysis is essential for ascertaining the characteristics of a projected flooding. Flow rates for exceptional floods are estimated by extrapolating statistical adjustments. The relevance of a model's outcomes therefore depends also on the quality of its hydrological input. Lastly, mathematical or physical modelling methods are relatively cumbersome and costly.

There are other, less laborious methods for determining natural hazards. The hydro-geomorphological method is predicated on analysis of the topological features shaped by the watercourse so as to determine the areas that could be inundated by the highest floods or the more frequent flood levels. Morphological analysis can produce a simple model of the alluvial environment thanks to precise determination of the various types of beds (minor, average, major) which each correspond to a class of flow: yearly average, frequent flood and exceptional flood. Historical analysis consists in finding archived descriptions of the greatest observed floods, to deduce the areas likely to be affected under current conditions.

Combining these methods with geographical information systems (GIS) provides instructive tie-ins with administrative, socioeconomic and other data, and enhances communication of the results to policy makers and the public at large.

This communication dimension is fundamental – local populations need to incorporate risk awareness into their culture. Yet modelling also has its pitfalls. Its "scientific" nature might lead some people to believe that the results of the model correspond to reality. Also, modelling allows a certain level of "prediction", it is not immune from errors – and its results could (none the less) be used “mechanically” to make zoning regulations.

Assessing climate variability

The evolution of the world climate is determined by the action of the atmosphere, the oceans, the terrestrial biosphere, the cryosphere (comprising sea ice, glaciers and snow cover) and land surface. A reliable representation of global climatic phenomena therefore has to model each of these components as well as their interactions. Our understanding of such interactions, and therefore our ability to simulate climatic evolutions, have substantially improved in the past years. Nowadays computer simulations use a large range of climatic models that vary according to, *inter alia,* the accuracy with which the various elements (*e.g.* clouds) are modelled, their spatial resolution (*i.e.* the number of reference points representing climatic conditions over the globe) and their overall complexity. A model incorporating all available knowledge concerning the climate system is totally unmanageable in present conditions. Therefore, a common practice is to simplify models – notably by replacing detailed modelling of some processes by empirically estimated parameters – in order to obtain reliable and at the same time workable representations of climatic phenomena in connection with an issue of interest. Projections of CO_2 concentrations in the atmosphere, for instance, concentrate on the carbon cycle, *i.e.* of exchanges of CO_2 between the atmosphere, oceans, and the terrestrial biosphere (International Panel on Climate Change, 2000).

A large range of natural disasters, in particular floods, windstorms, ice storms and droughts, are related to the frequency and intensity of extreme climatic events, and more generally to weather variability. Projections of average climatic conditions increasingly tend to indicate that the likelihood of such extreme events will increase in many parts of the world in the course of the century. Water vapour concentration in the atmosphere is expected to increase exponentially with the rise in temperatures due to global warming, leading to more frequent and intense episodes of high precipitation. As a consequence, floods, landslides, mudslides and soil erosion are also expected to become more frequent in the future. Other hazards that will likely worsen include droughts in most mid-latitude continental interiors, tropical cyclones, and Asian summer monsoons (International Panel on Climate Change, 2001).

However, forecasting more precisely long-term changes in the *variability* of weather at a local scale necessitates highly detailed and complex models where, in addition to average global changes, a host of specific factors are involved, such as the action of aerosols (which can have widely different geographical concentrations), the influence of winds and oceanic currents, or retroaction from clouds and the snow cover (IPCC, 1997). Some of the fundamental interactions, such as those between oceans and the atmosphere, are still poorly understood. And the scale of most extreme events is smaller than the grid of computer models, even those with the highest resolutions. Characterisation of decade-to-century climate variability today remains a major topic of research (NRC, 1998). As a consequence, to quote a recent report on the implications of climate change for Europe: “Policies can currently not be based on spatially comprehensive assessments of regional threats that may occur in the future” (Parry, 2000).

Case Study 2 – Nuclear Accidents

Assessing the cost of nuclear accidents

Until the beginning of the 1980s, assessment of the consequences of nuclear accidents focused on the costs of short-term countermeasures (*i.e.* emergency management). After the Three Mile Island accident, it was broadened to include emergency planning and preparedness. After Chernobyl, it was felt that at least regarding large-scale accidents, long-term social and economic impacts were not adequately covered, and the scope of consequence assessment had to be extended further.

The methodology of probabilistic consequence assessment (PCA) summarised here was recently set up by a group of international experts gathered by the Nuclear Energy Agency (OECD – NEA, 2000). The scope of the analysis is limited to off-site consequences of large nuclear accidents (comparable to Three Mile Island and Chernobyl); it excludes smaller accidents as well as release of radioactive substances.

The total cost of an accident is measured as the sum of the opportunity costs for all the individuals affected. The various consequences involving such costs are: countermeasures necessary to reduce doses; radiation-induced health effects among the exposed population; psychological effects; impact on the activity in which the installation functioned (*e.g.* power generation); long-term economic, social and political impacts; and environmental impacts.

In practice, PCAs usually consider only the three first categories (*i.e.* the direct consequences), "described in terms of cost of the implementation of countermeasures" (OECD – NEA, ibid). Direct consequences might appear only after a significant delay (*e.g.* latent or hereditary health effects). In such cases (delays of more than a year), economic assessment is faced with the difficulty of choosing a discount rate that would not "obliterate" the distant future. Increasingly, there is a consensus on using a normal discount rate for marketable goods and services, a reduced rate for medium-term impacts on non-marketable goods, and an even lower rate (possibly zero) for long-term impacts.

The cost of countermeasures is generally evaluated as part of the decision-making process, to choose the optimal level of intervention. Typical countermeasures consist in population movement (compulsory, voluntary or restricted movement) with transport and accommodation costs (short-term evacuation or long-term relocation) and losses of income and of capital; agricultural restrictions; and decontamination.

Radiation-induced health effect costs fall into three groups: direct health care costs, that are directly derived from the duration and cost of treatment of each type of care; indirect costs, due to the loss of earnings resulting from inactivity/death, which are generally evaluated with the human capital approach; and non-monetary costs (pain, etc.) that are often estimated by subjective measures such as the willingness-to-pay.

Case Study 3 – Infectious Diseases

The long-term economic cost of infectious diseases

Over the years, research has been able to demonstrate that there are direct links between health indicators, such as life expectancy, and economic performance. Certain variables, *e.g.* geography and demography, manifest an indirect link with economic growth. Geography is highly correlated with disease burden, which in turn influences economic performance. Demography, on the other hand, is partly determined by the population's health status, and this impacts directly on economic growth through the age structure and in particular through the proportion of the population who are of working age. Improvements or declines in life expectancy (*e.g.* through changes in infant and child mortality rates) are powerful predictors of economic growth over subsequent periods.

At the turn of the century, infectious diseases are the biggest killers of children and adults world-wide, causing an estimated 14.7 million deaths. HIV/AIDS, tuberculosis and malaria together accounted for 5.7 million of these, the vast majority in developing countries. Without significant progress being made, the overall figure of infectious disease mortalities is expected to change little. Yet it is estimated that by saving an additional 8 million lives per year through well-targeted measures, economic benefits of around USD 360 billion annually would be generated by 2015/2020. The impact of infectious diseases on individual countries is huge. In South Africa for example, predictions are that the HIV/AIDS pandemic will depress GNP by 17 per cent over the next decade.

Also for developed countries, a wave of infectious disease on a major scale could be very costly to the economy. World experts agree that another influenza pandemic is inevitable and possibly imminent. The impact could be devastating. Epidemiological models project that it is likely to result, in industrialised countries alone, in 57 to 132 million outpatient visits, 1.0 to 2.3 million admissions to hospital and 280 000 to 650 000 deaths in less than two years. The US Centers for Disease Control and Prevention (CDC) estimate the potential loss to the US economy alone at between USD 71 billion and USD 166 billion.

Source: Kassalow, 2001; WHO, 2000, 2001, 2003.

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Case Study 4 – Terrorism

The changing nature of terrorism

The 11 September 2001 attacks on New York and Washington and the October 2002 bombing in Bali vividly demonstrated that acts of terrorism have reached an unprecedented scale. In many countries, people as well as policy makers have realised that this category of risk now constitutes a major threat to society. Today one speaks of "new", "mega", and "catastrophic" terrorism. This case study attempts to document how terrorism has changed in recent years. Its message is not that the traditional forms have disappeared and been substituted by new, global forces exclusively threatening OECD countries. Old terrorism actually survives, and very often imposes considerable human, economic and social tolls on non-member countries (from Sri-Lanka to Colombia). The object of the study, rather, is to analyse the consequences of emerging forms of terrorism for risk assessment in OECD countries.

The difficult task of defining terrorism

Terrorism is a broad and at times fuzzy notion. It has been used to designate a variety of actions in different political settings and historical conditions.

Legal definitions, where they exist, can vary widely. In US legislation, for instance, terrorism is defined as "premeditated, politically motivated violence perpetrated against noncombatant targets by subnational groups or clandestine agents, usually intended to influence an audience" (United States Code, Title 22, Chapter 38, Section 2656f). A recent recommendation of the Council of Europe uses substantially different terms, considering as a terrorist act "any offence committed by individuals or groups resorting to violence or threatening to use violence against a country, its institutions, its population in general or specific individuals which, being motivated by separatist aspirations, extremist ideological conceptions, fanaticism or irrational and subjective factors, is intended to create a climate of terror among official authorities, certain individuals or groups in society, or the general public" (Council of Europe, 1999).

At the international level, attempts to arrive at a consensual definition of terrorism began in 1937 under the League of Nations, and have systematically failed since. Recent proposals included, in particular, relating terrorism to the notion of war crime, for which an accepted definition is available (deliberate attacks on civilians, hostage taking, and the killing of prisoners). Terrorism, then, would be characterised as the "peacetime equivalent of war crimes" (Schmid, 1993). Such efforts, however, did not lead to the adoption of a universal definition of terrorism.

Terrorist acts can be characterised by four features: their aim; their targets; the identity of their perpetrators and sponsors; and their means (OECD, 2002b). According to all four criteria, some terrorist acts of recent years represent a departure from past experiences of terrorism.

Aims

Traditionally, terrorism was the work of organised groups with identifiable political goals, such as national liberation. Terrorism was used as a bargaining counter to attain a clearly defined objective, *e.g.* freeing of prisoners, withdrawal of an army from an occupied zone. Of course there were campaigns designed simply to destabilise the political climate, but these were the minority. The new terrorism is totally different from this, in that its aim may be sustained opposition to an entire economic, social, political and cultural system.

As a consequence, the new terrorism is more global than terrorism has ever been. Previously, terror acts were international only in the sense that they may have been carried out in a country other than the country of origin of the particular group, for instance in plane hijackings or embassy bombings. The objective, however, was in the country whose interests were attacked. So while the operations may have had an international dimension, they were still carried out within a nation state-based context. Modern terrorism, by contrast, aims primarily at the "Western system", incarnated by OECD countries but also by their citizens and organisations abroad, by a variety of international institutions, and also by specific social groups of non-member countries.

Targets

As became obvious with the events of 11 September 2001, terrorist attacks can nowadays be meant to kill as many people as possible among the civilian population. In fact, recent terrorist acts accentuate a trend towards targeting large numbers of civilians that began in the 1980s. It was observed, for instance, that the number of transnational terrorist acts decreased by close to 60% between the 1980s and the 1990s, while at the same time the number of fatalities and injuries caused by such acts increased by 20% (Sandler, 2002). Places of gathering such as metro and train stations, commercial malls and large buildings have therefore become natural targets for terrorism. Some hazardous installations such as chemical plants, nuclear power plants and dams represent an even greater catastrophic potential.

New terrorism can also try to take advantage of the reliance of modern societies upon critical infrastructures such as energy, water, transport, health care, financial services and information systems. Attacks which would affect key elements of these systems to disrupt their functioning or take over controls for a significant length of time would entail considerable human and economic costs. In this respect, information, communication and control systems have become highly attractive targets for terrorists, as they have become essential components of most critical infrastructures in the past two decades.

From the standpoint of terrorist movements, "netwar" offers a number of advantages: expertise for the attacks is available, and can be hired – at least to a certain extent; groups can be organised in networks, with small, dispersed but co-ordinated nodes focusing their attacks on a specific target; the benefits of a successful attack, in terms of damage inflicted, can be very substantial; the costs, in terms of terrorist lives, risk of capture and even funding, are limited; and a successful attack would gain worldwide publicity whereas failure would go unreported (unless governments and corporations develop a specific communication strategy based on reporting attack failures). One estimate suggests that 30 computer experts with a budget of USD 10 million could cripple the United States (Center for Strategic and International Studies, 1998).

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Agents

Traditional terrorism is the deed of well-structured groups of extremist militants, often with the backing of local or national political forces. Modern terrorists, by contrast, are difficult to localise. Due to the availability of material and knowledge to produce weapons, they do not need to rely upon heavy structures for financial, technical or logistical assistance. Very small groups of individuals can nowadays organise large-scale attacks and cause massive damage, as in the 1995 bombing in Oklahoma City. At the same time, the increased mobility of people, goods and information has enabled some terrorist structures to develop in networks. As exemplified by al-Qaeda, such networks can link together myriads of small and medium units, each of which can enjoy a large degree of operational autonomy. An organisation such as al-Qaeda is not state-based, but truly international. One consequence of this is that the distinction some countries make between foreign and domestic terrorism is no longer valid (Gilmore Commission, 1999).

The ideological spectrum of terrorist organisations in OECD countries has also widened. While for a long time it was mainly made up of extremist left doctrines on the one hand and nationalism and ethnicism on the other, it now covers religious fundamentalism, millenarist cults and other forms of fanaticism. The Aum Shinrikyo sect, which killed 11 people and injured almost 3 796 during its 1995 sarin gas attack in the Tokyo metro, is but one example.

Finally, some states have become more active – if less open – sponsors of terrorism. Terrorist groups have occasionally benefited from the backing of states for a long time. However, in the two past decades and in particular after the collapse of the former Soviet Union, states openly supporting terrorism have become increasingly scarce – which explains, for instance, that aeroplane hijackings have receded. Instead, a number of states have developed occult but important links with terrorist organisations. For a number of countries, encouraging, using and sometimes even organising terrorism has become a strategy for gaining diplomatic influence, or a low-cost, low-risk alternative to war.

Means

The vast majority of recent terrorist acts have been committed with conventional means (traditional explosives, guns, etc.), or even improvised weapons (bottled gas, blades, etc.). However, the 1995 Tokyo sarin gas attack and the dissemination of anthrax spores in 2001 in the United States, for example, call attention to the emerging use of unconventional means: bioterrorism, chemical weapons and, more hypothetically, nuclear attacks. All three classes of weapons have been produced for decades by some governments and have tended to proliferate, and therefore to become more accessible, in recent years. It is the role and responsibility of governments to impede to the extent possible access to this material.

Biological weapons could well be the most dangerous: they can be extremely deadly and are easy to procure and difficult to detect. The facilities required for producing and dispensing biological warfare agents are easily concealable, and almost indistinguishable from production facilities for pharmaceuticals and vaccines. Fortunately, many of those agents do not survive well in an open environment. It would be complicated to build a bomb or missile that would not destroy them in the explosion. Water supplies would also be difficult to target, given the huge amounts of agent needed and the effectiveness of water purification systems. The most practical way to release the toxins is probably via an aerosol.

A bioterrorist attack is often compared to the upsurge of a new infectious disease, and might actually be difficult to distinguish from the latter. When the West

Nile encephalitis first appeared in New York in 1999, intelligence officials suspected that the virus had been introduced intentionally, before finding that it probably was not (Stern, 2001). As the pathogen agent involved in a bioterrorist attack can be unknown, it might be extremely hard to predict how and at what speed it is going to propagate, which populations it is more likely to affect, and how and to what extent it can be treated. Therefore, the effects of the attack may not become known for days or even weeks. Management of the bioterrorist risk therefore entails permanently mobilising every element of the response chain, from surveillance, identification and alert – in particular, global disease surveillance – to prevention, treatment and communication (Knobler, Mahmoud and Pray, 2002).

Chemical weapons, using compounds that affect skin, blood, or the nervous system, can also be highly lethal. As for biological agents, they are generally considered easy to obtain or produce but difficult to maintain in stable conditions or to disperse effectively. However, the Tokyo sarin gas attack shows that deadly strikes are possible.

Nuclear attacks, finally, can involve three types of means: industrially fabricated nuclear weapons, improvised nuclear devices, and radiological dispersal devices. It is usually considered that terrorist movements could not gather the resources to produce a nuclear weapon without the active support of a state. The supply of fissile material is strictly monitored by the International Atomic Energy Agency, and its diversion for terrorist purposes would not go unnoticed. Still, leakages do exist. For instance, recently, Russian officials declared that about half the country's stock of weapon-grade radioactive material was inadequately secured, and that several grams of it have been reported missing in the past ten years. International co-operation to control access to such material therefore needs to be reinforced.

Terrorists are less likely to be in possession of a nuclear bomb than to attempt to use a much less sophisticated device, *e.g.* release radioactive material obtained from a reprocessing plant or weapon decommissioning with a "dirty bomb". Simple radiological material would be easy to collect and its dispersion, although unlikely to cause substantial damage, could have important psychological impacts.

Consequences for risk assessment

Terrorism will probably be a key feature of conflicts in the coming decades. Its recent mutation makes it liable to cause immense human and economic damage. Better understanding and assessment of the threats that it engenders for society is therefore imperative. The potential use of weapons of mass destruction must receive particular attention, whether in terms of intelligence gathering, protective measures or preparedness. For a wide range of activities, sites and systems, risks of terrorism have to be assessed and handled in a systematic and effective way: energy systems, in particular electricity grids, nuclear power plants, and oil and gas storage facilities; agriculture, food and water systems; information and telecommunication infrastructures; transportation systems; and high-density areas in cities.

However, terrorism differs from most other types of risk in two ways that make its assessment difficult. First, its risks cannot be quantified using historical data, not least because of the deep changes they have undergone in the past years. Second, they are generated by human behaviour. In other words, the context of terrorism risk is one where damage is not caused by an exogenous event such as an earthquake or even an accidental human error, but by the deliberate action of persons resolved to exploit every breach in security, and who may be ready to sacrifice their lives doing so. Events such as a large aeroplane colliding with a nuclear power plant or a lethal bacterium contaminating a food production process are considered in safety assessment procedures, but very seldom as the results of a deliberate act. In such areas,

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methodological work is needed to integrate the risk of malevolent acts into the framework of risk analysis, and to develop methods of quantifying that risk. The existence of such tools is a prerequisite for effective protection measures aimed at reducing vulnerability (see Case Study 4, Chapter 3), as well as for risk-sharing mechanisms such as terrorism insurance (see Case Study 4, Chapter 5).

A number of innovative ideas have been put forward for modelling terrorism risks (Major, 2002; Woo, 2002), and recently several models have been developed. Based on experts' opinions (collected *e.g.* via Delphi methods) and/or game theory models of behaviour, they evaluate the likelihood that a given location becomes the target of a terrorist attack and the likelihood that the attack succeeds. A loss simulation module then estimates the damage incurred.

Still, such quantification tools rely upon an adequate understanding of terrorism threats, which is first and foremost an intelligence issue. Information needs not only to be collected as broadly as possible, but also to be analysed and communicated effectively. One solution for this is to direct data from all sources towards a unique capability, which has the responsibility of consolidating and analysing information (Gilmore Commission, 2000). Better sharing of knowledge of terrorist networks and information on terrorist actions internationally is, of course, crucial. In addition, assessing the threats of terrorism requires not only a better understanding the origins, methods and organisations of terrorist groups, and control of the channels and means terrorist organisations are known to use, but also finding the channels and means that they *could* use. Because of terrorists' ability to continually change their tactics according to the opportunities and obstacles they face, the risk of attacks and the effectiveness of security systems built against them have to be continuously reassessed.

Case Study 5 – Food Safety

The emergence of international standards of food safety assessment

A variety of agents and substances can affect human health through food: microorganisms such as bacteria, viruses and prions; mycotoxins (fungi), phycotoxins (algae), and other natural toxic substances; and hazardous chemical compounds used in agriculture or in food production, such as pesticides. For some of these, traditional risk assessment methods based on dose-response relations are not reliable. The action of many biological agents, for instance, is highly influenced by their environment (including the human body), and it can change very rapidly due to mutations. Hazardous substances or agents can enter the food chain at any of its stages depending on a variety of factors, including the behaviour of the food's consumer.

Thus, more than for most other types of risk, food-borne risks result from the interaction between a causative agent and human and social behaviour. Consequently, any efficient food safety system needs to be based not only on a systematic procedure of hazard assessment applied to the whole of a food chain, but also on sound hygiene practices all along that chain, from agriculture to consumption. With changing patterns of consumption and the development of trade in agro-food products, assessment and control of food-borne risks entails a global monitoring of food production. The World Trade Organisation's Sanitary and Phytosanitary (SPS) agreement reflects such a need, and has led signatory countries to base their sanitary and phytosanitary measures on international standards, guidelines and recommendations, where they exist.

Important international fora have been created with the aim of gradually harmonising food safety standards and regulations. The most influential of these is the Codex Alimentarius, a joint commission of the World Health Organisation and the Food and Agriculture Organisation. Through this commission, 167 countries adopt standards for commodities, codes of practice and maximum limits for additives, contaminants, pesticide residues and veterinary drugs. For example, the Codex Alimentarius has recommended the implementation of its General Principles of Food Hygiene and of Hazard Analysis and Critical Control Point (HACCP) plans as the bases of a reliable food safety system. These are generally recognised as the best science-based food safety assurance system developed to date.

HACCP was born as a space-age technology designed to keep food safe in outer space. It was consequently developed by United States Food and Drug Administration in 1970, and adopted as a food safety programme for the country's food supplies. It is now one of the central elements of food safety systems in most OECD countries.

HACCP is based on a systematic identification and control of risk through the phases of food production, from buying raw materials to delivering the final products. It involves seven steps:

1. *Hazard Analysis*. The various hazards that may affect food safety are identified. Their likelihood of occurrence is quantified. Below a certain level of likelihood, hazards are excluded. The various biological, chemical or physical parameters

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reflecting the occurrence of every remaining hazard (and therefore to be controlled) are listed.

2. *Identification of Critical Control Points (CCPs)*. Every step of food production and handling where one of the selected hazards could be introduced in the process is pinpointed.
3. *Establishment of preventive measures with critical limits for each CCP.* A critical limit is determined for every control parameter, below which the occurrence of hazard can be considered unlikely. Critical limits may be specified in regulations or guidelines, or may be established at the plant level through literature surveys, experimental results and expert consultations.
4. *Determination of procedures to monitor the CCPs*. Monitoring through testing and observation helps to track the entire process, to determine when and where a CCP reaches a critical limit, and to provide written records.
5. *Planning of corrective actions to be engaged* when monitoring shows that a critical limit has been reached.
6. *Creation of procedures (supplementary tests) to verify that the system is working properly.* Periodic and comprehensive verification has to be conducted by an unbiased and independent authority.
7. *Ensuring effective record keeping* in order to document the various HACCP procedures.

As Critical Control Points are specific to the production process, HACCP plans have to be adapted to each process.

The effectiveness of HACCP systems in identifying and controlling food-borne risks naturally relies on a number of hygienic and technical prerequisites. To establish such foundations, codes of practice, standards and guidelines (such as the Codex Alimentarius General Principles of Food Hygiene), as well as training, are necessary. National regulatory authorities have to define the environmental and operational conditions necessary to ensure food safety for each segment of the food industry: agriculture, farming and fishing, manufacturing, transport, storage and trade. Such conditions generally consist of a series of minimum requirements concerning the methods, facilities or controls to be used in the production, quality control, holding and distribution of products intended for human use (including the personnel necessary to perform the assigned tasks, the prescription of a quality control unit, and equipment characteristics).

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ISBN 92-64-19947-0
Emerging Systemic Risks in the 21th Century
Risk Prevention

Chapter 3

Risk Prevention

Abstract. *This chapter is about actions aimed at preventing disaster, or at reducing its consequences before it occurs. In the area of emerging systemic risks, these actions fall into two categories. The first are called "protective strategies" in this report; they have to do with protecting a specific system against hazards or reducing its vulnerability. The second category, "framework conditions", consists of measures to implement and enforce risk prevention, regulate liability and compensation, increase transparency and availability of information, and so on. The chapter highlights the special challenges to prevention which systemic risks pose.*

Executive Summary of Chapter 3

Considerable progress has been made to date in risk prevention thanks to significant advances in knowledge, technology and skills. However, a recurring theme in this book is that the risk landscape is constantly changing, as is the very nature of many risks. The pressure is thus on risk management to stay abreast of these changes. A set of interrelated challenges for the future are the timely provision and use of information; the design and implementation of specific measures aimed at protecting systems or heightening their resilience; strengthening co-operation and co-ordination domestically and internationally; raising the level of risk awareness, preparedness and commitment; and enhancing the implementation and enforcement of preventive measures. An overriding concern with all these challenges is to marshal the necessary resources, transfer vital knowledge to where it is needed, and accelerate the transition from what are at present nationally driven concepts of prevention to internationally-based strategies.

Common factors across the entire spectrum of emerging systemic risks are the need for information gathering, early warning, and the timely identification of vulnerabilities. In some areas – e.g. *nuclear accidents, natural disasters (hurricanes, flooding) and infectious diseases – a number of sound monitoring and early warning mechanisms are in place, especially in developed countries. The growing interdependence of economies and societies across the globe, however, means that emerging risks in developing countries, where monitoring and early warning systems are often inadequate or nonexistent, can rapidly spread. That makes it imperative to strengthen international co-operation and co-ordination so as to transfer knowledge, skills and technologies and thereby close potentially dangerous loopholes in the overall coverage of the monitoring effort. The prospect of new threats in the form of drug-resistant diseases, cyber-terrorism, bioterrorism, etc. only serves to emphasise the urgent importance of stronger international collaboration.*

*Measures to protect systems or at least enhance their resilience to disruption and/or attack fall into two broad categories: steps designed to strengthen vulnerable points in the system (*e.g. *by constructing dams, building protective shells around nuclear power plants), and steps to make the "architecture" of the system, an increasingly key element, more resilient. The latter is especially relevant to critical infrastructures. Terrorist attacks, cyber-crime and certain natural catastrophes highlight the need to design critical infrastructures with their growing interdependence in mind. Particularly in energy, information/communications and transport, even minor disturbances can*

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*snowball into major disruptions. Among the issues examined in this chapter are the growing reliance in some activities on commercial, highly standardised off-the-shelf technology; lack of diversity in systems providers; and the security trade-off involved in decisions to centralise or decentralise networked systems. In both critical infrastructures and other complex systems such as hospital centres, the presence of redundancy in the system can be key to its robustness. Thus, in case of failure of the primary mechanisms or processes (*e.g. *disruption of fully automated air traffic control, failure of front-line safety mechanisms in nuclear power plant operation, swamping of emergency medical facilities), back-up systems are available to take up the strain. However, to the extent that tighter criteria of economic efficiency apply in overall economies, the principle of in-built system redundancy may be called increasingly into question.*

Societies' performance in managing risks is, of course, determined not only by specific protective measures, but also by the framework conditions they establish to shape interaction among the various decision makers. Although framework conditions vary widely from one country and one risk area to another, they are currently dominated by a number of common developments. These include the loss of effectiveness of centralised modes of risk management, a trend towards broadening liability, and the development of a "claim culture".

*Against the background of these developments, the setting of effective frameworks for managing emerging systemic risks can be truly challenging. To begin with, in an increasingly decentralised, market-based society the widespread promotion of risk awareness and preparedness becomes a prerequisite, as does a broader-based commitment to risk prevention. Keener competition, privatisation of natural monopoly network industries and services, deeper market integration and more liberalised international market access all help to stimulate activity and energise innovation, but they also heighten the emphasis on cost-effectiveness and profitability. A central issue is whether and to what extent these developments also place pressure on operational safety margins (*e.g. *chemicals production, super-tankers, the animal feed industry), on the transparency of reporting on safety issues (*e.g. *for fear of divulging commercially sensitive information), or on the capacity of market players and their regulators to render their vast network systems sufficiently resilient to withstand major disruption (*e.g. *national rail networks; the information systems required to operate pan-European electricity generation and transmission). Better use of tort law and the insurance system and more effective implementation of existing regulations also stand out as major challenges for future preventive strategies.*

The complexities are huge and the borderlines of responsibility constantly shifting. It is therefore essential to develop synergies in the risk prevention arena, for instance in the form of public/private partnerships.

1. Introduction

Risk prevention involves various types of actions aimed at controlling the driving forces that influence risks, at mastering the hazard itself, and at mitigating the resulting damage. In this chapter, only *ex ante* mitigation measures are considered (*i.e.* those taken before an emergency situation occurs, such as the construction of dykes or flood corridors). *Ex post* mitigation measures (*e.g.* evacuation) will be analysed in Chapter 4.

The prevention measures can be split into two broad categories. They can aim at putting in place protection against specific hazards or at reducing the vulnerability of particular systems. These might be called "protective strategies" of risk prevention. The second has to do with a society's "risk culture", determined by a variety of factors: how risk prevention measures are implemented and enforced; liability and compensation rules; economic incentives; transparency and availability of information; and everything that influences attitudes toward risk. These factors will be called the "framework conditions" of risk prevention.

This chapter reviews a series of major challenges facing societies in preventing emerging systemic risks. Those concerned with protective strategies are the need for information gathering, early warning and the timely identification of vulnerabilities; the design and implementation of specific preventive measures, most notably those aimed at protecting critical infrastructures; and the growing need for structures and mechanisms, particularly at international level, that foster co-operation and collaboration in risk prevention. Concerning framework conditions of prevention, the focus is on the loss of effectiveness of traditional command and control approaches; the importance of commitment to risk prevention; and conditions for risk awareness and preparedness. In each case, thoughts are offered on the current state of response to these challenges. The final section offers a set of cross-sectoral lessons.

2. Protective strategies of prevention

The present situation

Many of the forces that appear to be heightening risks and complicating the task of prevention – technological progress, growing interdependencies, the spread of networks, increasing mobility of people, goods and information within and across borders, deeper integration of markets, etc. – at the same time provide useful tools for reducing the risks and preventing the hazards in question. Vulnerabilities in information and communication systems can be combated by sophisticated security technologies. Exposure of settlements to pollution or other threats can be mapped by satellite. Expertise from around the globe can be mobilised quickly to tackle emerging diseases. There are many examples.

As the following will show, however, there are important limitations weighing on societies' capacity to bring the necessary resources to bear on such matters as risk monitoring and preventive countermeasures. Some of these limitations are of course technical and await the requisite innovations. Many more are grounded in an inability to marshal the necessary resources in the first place, to transfer vital knowledge to where it is needed, to overcome institutional obstacles and to achieve an effective transition from nationally driven preventive concepts to internationally-based strategies.

Challenges

There are three categories of challenges facing prevention: timely provision of information and application of knowledge to reduce exposure to catastrophic events; design and implementation of specific measures to protect systems or at least heighten their resilience; and engendering or enhancing interaction among the key players and institutions to enable or strengthen implementation. The threat of terrorism, for instance, has recently shed light on those challenges (see Case Study 4).

Information and knowledge

In the developed world at least, planning for catastrophe has a set of common tools. The first of these are directed at reducing risk prior to an event occurring and at diminishing exposure to disaster: information gathering, early warning, and the timely identification of the vulnerabilities. Indeed, these tools are needed across the spectrum of risk areas.

Health is a useful starting point. In the past 20 years approximately 30 new diseases have emerged, including HIV/AIDS, Ebola virus, hepatitis C and the Hanta virus. Over the same period, tuberculosis, malaria and cholera have gained in virulence. Six infectious diseases – HIV/AIDS, tuberculosis, malaria, pneumonia, diarrheal infections, and measles – are responsible for around half of all premature deaths worldwide (WHO, 1999). As international movements of people and merchandise intensify, so too does the risk of disease. To compound problems, many diseases are becoming difficult to treat, not least due to the misuse of antimicrobial medications and lost opportunities to tackle infectious diseases on a major scale in poor developing countries. With 1.6 billion people expected to be travelling abroad each year by 2020, a lethal disease, flu epidemic or drug-resistant "super bug" could pose a heightened risk of major proportions (Kassalow, 2001). Without adequate capabilities to identify, report and monitor such events, the prospects of controlling disease are indeed grim.

Natural disasters are further examples. Early warning of impending floods, earthquakes or windstorms contribute greatly in taking appropriate counter-measures to reduce the ultimate toll on human life and property. In some areas, however, the likely need for prevention is only beginning to emerge. A case in point is increased solar activity, associated with sunspots and solar flares, which sometimes produces geomagnetic storms on earth. These can have seriously disruptive effects on electric power systems and on communication and navigation systems, costing billions of dollars. Geomagnetic storm forecasting systems could prove extremely useful in providing early warning.

Existing capacities to handle information gathering, surveillance and reporting are of course very unevenly distributed among countries and regions. Indeed, many developing countries are extremely poorly served in this respect on virtually all fronts – health, natural disasters, environmental pollution, and so on. Information and knowledge transfers therefore take on a vital role in ensuring that these countries are able to improve their lot. In a compartmentalised world, this would be the extent of the problem. However, rapidly growing global interdependence adds a further, more urgent dimension to the sharing of knowledge. Disease, toxic substances, dangerous waste etc. do not stop at national borders. They spread across borders and eventually feed back into the developed world.

Let us take just two examples. First, in the late 1990s the United States registered over 18 000 cases of TB. More than two-fifths of these cases originated in foreign-born people (Ruggiero, 2000). Second, changes in global economic structures have seen the location of certain production activities shifting increasingly to developing countries, taking with them the production methods but not always the safety techniques and standards. As a result, some hazardous substances are present in various agricultural or manufactured products of these countries, and others are released into the environment. In both cases, they can reach distant endpoints, including OECD countries (see Illustration Box 1).

Design and implementation of specific preventive measures

The second set of tools at planners' disposal are specific measures aimed at protecting systems, or at least heightening their resilience. These can take two forms. One targets vulnerable points within systems, *e.g.* strengthening dams, building protective shells around nuclear power plants, fitting

Illustration Box 1. **Chemical safety in various parts of the world**

As underlined by a recent OECD Report, greater emphasis must be placed on the chemical safety infrastructure in non-OECD countries as the production and use of chemicals become ever more widespread:

> "In the future, more products will be manufactured by the chemicals industry in non-member countries than today, which could lead to a corresponding *shift in risk* from OECD to non-OECD countries. Today, the level of occupational and environmental protection in developing countries is lower than in OECD countries. If this does not change, risks linked to the production of chemicals could increase significantly. Benzidine dyes are a case in point. The International Agency for Research on Cancer classifies benzidine as a Group 1 carcinogen and benzidine-based dyes as a Group 2A carcinogen. OECD countries phased out the manufacture of these dyes in the 1970s and 80s. However, during that same period other countries increased production to meet continuing demand (OECD, 1997). This also has been the case with pesticides that are banned in OECD countries but are still being produced and used in non-member countries, where workers are often less protected.
>
> Shifting production or use of certain chemicals to other countries could, in some cases, also increase risk in OECD countries. The latter may have strict limits on the amount of hazardous chemicals allowed in a product sold to consumers, but it is much easier to monitor these from the domestic production *and* consumption side than solely from the importation side. In some cases a pesticide whose use is banned in a member country is still made in that country but exported to a non-member country (under Prior Informed Consent procedures) where it is applied to fruits and vegetables that are exported back to the OECD country. Similarly, ceramic ware manufactured with glazes and decorations containing lead is traded internationally in large volumes. Since many OECD countries have standards for leaching lead from ceramics but many non-members do not, concerns have been raised about the importation of these products as they can be difficult to monitor for leachability.
>
> An increase in the production volumes of chemicals at factories in non-member countries could also lead to a higher risk. It has been found with certain persistent, bioaccumulative and toxic chemicals (*e.g.* persistent organic pollutants) and other substances (*e.g.* nitrogen and sulphur oxides) that once they are released from facilities during manufacturing/processing or through their final use (*e.g.* pesticide application), they can travel long distances before they are finally deposited on land or reach the atmosphere of local communities. If non-member countries do not employ

Illustration Box 1. **Chemical safety in various parts of the world** *(cont.)*

the same kinds of controls on emissions and use as OECD countries, a shift in production to the former could lead to greater emissions and subsequently to greater concentrations of these substances in the environment in both non-member and member countries."

Source: OECD, 2001.

supertankers with double hulls, employing vaccines against infectious diseases, and so on. The other aims at making the "architecture" of the system more resilient. This latter category of measure is particularly (but not uniquely) important for critical infrastructures.

Information and communication systems immediately come to mind. Public telecommunications networks (PTNs), the Internet and an increasing number of extranets and intranets connect emergency services, financial networks, military command-control systems, gas and oil pipeline systems and educational systems, to name but a few. Growing complexity and interdependence, particularly in energy and communication infrastructure, means that even minor disturbances can snowball into, for instance, regional power outages. Technical complexity may also permit major disturbances to go unrecognised and compound until failure occurs. One of the most important vulnerabilities lies in the interdependency between PTNs and the Internet, in the sense that the Internet depends heavily on PTNs and the latter in turn depend on electrical power operations, satellites and optical cables.

In the case of banking and finance, many back-up systems and parallel arrangements create a high level of security. However, functions such as payment systems, securities and commodity exchanges, with their clearing and settlement organisations, are heavily dependent on telecommunications services and electrical power, and their breakdown – if improbable – would nonetheless risk affecting the economy at large.

The sector of physical distribution is increasingly reliant on ICTs to shorten lead times, route and schedule traffic, tracking, etc. This means that vulnerabilities in the ICT structure could affect every aspect of the transportation industry and its dependent downstream systems. Future challenges may be found in the operation of Global Positioning Systems (GPS) – soon to become the sole basis for radio navigation – and in the modernisation of air traffic control functions:

- A recent report by the Volpe National Transportation Systems Center addresses the vulnerabilities of various transportation modes to unintentional and intentional disruptions. It identifies for example the extremely low power signals (only one of which is available for civil aviation use) as a potential problem, and also points to possible disruption from ionospheric interference, radio frequency interference, and jamming.

- The US Federal Aviation Administration (FAA)'s air traffic control facilities have so far proved resilient because a security incident at one facility cannot spread to another. Each of the 20 centres managing long-distance air traffic can operate independently. However, this isolation of FAA computer systems is increasingly being questioned as pressure grows to improve efficiencies by interlinking systems. (Mehan, 2000).

At the firm level, emerging organisational technologies such as enterprise resource planning (ERP) and electronic data interchange (EDI) allow customers to access inventories, prices and other data in the company. Because of the interconnectedness of back-office systems and order-entry and customer service departments, even a small disruption may resonate to the customer. As online business-to-business and business-to-consumer relations grow, so too will potential vulnerabilities. Cyber attacks on information and communication systems illustrate this point well.

Among the "architectural" features that could make ICT systems vulnerable are the growing dependence in some quarters on commercial off-the-shelf technology and in-place commercial networks; lack of diversity in system providers whose products are incorporated into a particular network; lack of redundancy in the system; and the trend among some network providers of using a single private-Internet core to support network management and operations systems instead of numerous dedicated independent leased line facilities for each system (Hayward and Personick, 1999). Moreover, there is some evidence of growing geographical centralisation of key computing capabilities and network hubs, and also of greater centralised management and control of ICT systems (Norwegian Ministry of Trade and Industry, 2000).

Where there is insufficient diversity and decentralisation of systems and their management, or significant lack of redundancy, robustness and reliability of the systems decline when (not one but) several simultaneous disruptive events occur. Thus for instance, in the FAA's air traffic control system, redundancy is a core element of the system design philosophy. Primary, secondary and manual mechanisms are in place to ensure operations continue under adverse circumstances. But there is growing concern that yet more system redundancy may be required to meet new and emerging threats that could effect several systems at once (Mehan, 2000). This holds true not only for ICT but also for other critically important infrastructures such as energy provision and health delivery systems.

Co-operative infrastructures

A third set of tools are those that engender or enhance interaction among the key players and institutions with a view to enabling or strengthening implementation of specific preventive measures. Recent cases of computer viruses, flooding and windstorms in various parts of Europe, foot and mouth disease in the United Kingdom, and more recently still, anthrax alerts in the United States and Germany underline the importance of properly functioning communication and co-ordination among the various communities involved – technical, medical, veterinary, public health, law enforcement, military, private firms, etc. – in preparing and implementing preventive steps. Some of these recent events have brought to light persistent institutional and logistical deficiencies.

The future holds yet more challenges as some of the key driving forces mentioned in Chapter 1 – notably the deeper integration of markets both regional and global, and the shifting borderline in economic activity between the state and the private sector – combine in some areas to increase potential vulnerabilities. The emerging Europe-wide market for energy is a case in point. As it becomes increasingly integrated, energy provision becomes increasingly interdependent, not only from the point of view of energy networks but also in terms of logistics – the supply of various types of fuel (gas, oil, coal, nuclear), the transportation systems, cooling water, etc. Beyond this, the information required to operate, control and ultimately protect the generation and transmission of energy will flow through open public information networks, as will communication among the players in the field – raising further security concerns.

It is inconceivable that efficiency and security can be assured in such a geographically vast and complex system without effective co-operation at all levels, *i.e.* not just among government departments within a country and between countries, but also and equally importantly between government departments and the private sector stakeholders in energy, transportation, communications, security, and so on.

The case for greater collaboration at international level emerges clearly from the current and future trends and developments set out in Chapter 1 and elsewhere in this report, in the fields of critical infrastructures, natural disasters, terrorism and health. Again, infectious diseases serve as a useful illustration of the benefits of international co-operation and the cost of its absence. The consequences of undue focus on national public health priorities in the case of antimicrobials strongly underlines the need for global strategies in this field. As Case Study 3 points out, by neglecting the modern globalised context in which infectious pathogens develop, some of these have been able to proliferate outside of national borders and then bounce back in mutated,

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drug-resistant form. For a number of the more familiar epidemic-prone viruses such as influenza, surveillance structures have been in place for some time. The WHO's global influenza network currently consists of about 110 national laboratories in over 80 countries, and four International Reference Centres.

The effectiveness of the international system, however – as in the case of surveillance structures for other infectious diseases – is only as good as the quality of the national systems allows. This applies to many developing countries, where there is for instance still a significant shortage of epidemiologists; but it also holds for the developed world. In the United States, for example, the Centers for Disease Control and Prevention have a relatively sophisticated surveillance structure: about 70 laboratories reporting on the number and type of influenza viruses isolated each week; state and territorial epidemiologists reporting on the level of influenza activity each week; a voluntary, national network of sentinel physicians; vital statistics offices in 122 cities reporting regularly on mortalities caused by influenza and pneumonia. Nonetheless, there remain areas in need of improvement. For instance, the capacity to detect an isolated (as opposed to a wider-based) event of influenza importation is thought to be very weak; most states lack contingency plans for rapid expansion of their basic influenza surveillance infrastructure; and there is concern about the ability to detect novel strains of influenza emerging in the United States (CDC, 2001).

Emerging responses

Surveillance

On the monitoring and reporting front, there are many clear indications of what might be viable and effective structures for the future.

Space activities and natural disasters present a useful illustration of advances in and the potential of surveillance techniques. In conjunction with a number of significant flood events in Europe and elsewhere in recent years, it has been possible to demonstrate the contribution of satellite information-application during the various flood phases. Technologies have emerged which extract from the original satellite data a stock of ready information for use by the relevant authorities. Meteorological information derived from space images is already used operationally by civil protection authorities. In the early warning phase, weather forecasts can be built into the modelling procedures and combined with estimates of soil water saturation, potential water runoff from melting snow, etc. More generally, research into early warning of natural disasters has made some progress over the last decade or so. Some methods that rely on space data, such as radar interferometry, can for example detect the first tiny displacements prior to volcanic eruption, and tectonic shifts that may lead to earthquakes. However, further development is needed to improve the reliability and sensitivity of these techniques.

A further example is that of surveillance systems for infectious disease which build on access to Internet-based information. The Canadian Global Public Health Intelligence Network (GPHIN) is one such illustration. GPHIN was developed by Health Canada in partnership with the World Health Organisation (WHO). GPHIN is designed to be an automated, time-sensitive, 24/7, electronically based system, which continuously scans multiple sources including the Internet. It amasses, from around the world, real-time information on public health events, including any outbreaks of the 31 communicable diseases. The information is disseminated through secure channels to provide early warning to Canadian and international partners, most notably WHO, for comprehensive risk assessment and response. In the same context, GIS is rapidly evolving as an epidemiological tool for infectious disease control. User-friendly mapping technologies are now employed to locate populations at risk of epidemic-prone diseases, identify conditions conducive to outbreaks, etc. and thus boost alert and preparedness systems.

A variety of instruments have also been developed to continually assess and monitor risk factors inside complex systems. Living probabilistic safety assessment (L-PSA), for instance, is a dynamic risk assessment tool developed in the past fifteen years in the nuclear industry (NEA, 1999). The aim of L-PSA is to constantly adapt probabilistic safety assessment models to evolutions in both nuclear power plant features and the relevant risk modelling. The result reflects the measure of risk at a specific time and under specific plant conditions. Ideally, major operational decisions (such as design or process changes) can then be tested and monitored in real-time according to their impact on risk and safety margins. Tools are also being developed to assess how prevention and mitigation measures modify the vulnerability of systems to various hazards, including for example in chemical plants.

Co-ordinated action to reduce network and other system vulnerability

A crucial element of prevention at national level is the ability not only to co-ordinate the various departments of government and public administration, health services, veterinary services, law enforcement, etc., but also to ensure a properly functioning co-operative relationship between the public and private sector.

Efforts at such broad-based co-operation and co-ordination would seem to stand a better chance of success when they benefit from high-level political backing. The United States is a case in point. In response to the findings of a presidential commission, a Presidential Decision Directive (PDD63) on "Protecting America's Critical Infrastructures" was issued in 1998: a major

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Illustration Box 2. **GIS application: decision-support system for flood emergencies in Australia**

The Nerang River system, located on the Gold Coast in southern Queensland, is in the unenviable position of having a number of residential canal estates and suburbs at risk from flooding. They were built over thirty years ago when flood plain planning practices were less sophisticated than they are today. In a 1-in-100-years average recurrence interval (ARI) flood event, the combined impact of riverine flooding and storm surge could affect perhaps 14 000 residential properties, of which some 5 000 to 7 000 dwellings could experience over-floor flooding, depending on the timing of individual rainfall bursts over the catchment area. In such an event, the depth of flooding in residential areas is unlikely to exceed 1 metre. Under probable maximum flood conditions, however, some 28 000 properties and over 50 000 people would be directly affected – with depths of flooding at 2 metres or more. What makes this situation different from most are the demographics of the population: a high proportion of retired people on fixed incomes live in the area, and some are physically unable to lift their more valuable possessions above flood waters.

The temporal patterns of rainfall in the Nerang River catchment area play a significant role in the estimation of peak flood levels and the magnitude of the flood volume. This is partly due to the nature and hydraulic efficiency of the streams, and also of the canals within those flood-vulnerable estates. The Nerang River catchment area can accept about 500 mm of rain over a 48-hour period without serious flooding, although some low-lying land would be inundated. However, if the heavy rainfall period extends beyond 48 hours, or the rainfall is more intense, the threshold of exposure to significant flood risk is crossed. Depending on the temporal pattern, peak flood levels can be reached anywhere between 40 and 65 hours after rain begins to fall in a standard 72 hour rainfall event. Because of the rainfall depth/intensity threshold effect, it may not be until 20 to 24 hours after the start of rain that a flood emergency becomes evident.

The difficulty for effective response is being able to predict peak flood levels. This can be done up to 6 hours ahead with reasonable guesswork based on advice from the Bureau of Meteorology's interpretations of radar images downloaded from its Internet site. However, flood levels can continue to rise after the initial 20 hours at 100 mm per hour (or more) for a further 20 hours, by which time the deadline for orderly evacuation may have passed. This means that a clear, well-ordered and structured evacuation plan needs to be in place and supported by a flood-response decision-support system.

Illustration Box 2. **GIS application: decision-support system for flood emergencies in Australia** *(cont.)*

The Gold Coast City Council has developed a series of hydrologic, hydraulic and geographical information system (GIS) modelling routines, and is now integrating them with evacuation modelling. This process relies on the following elements:

1. A process that converts one-dimensional (1D) flood model results to raster GIS.
2. Development of animations of standard floods.
3. Development of inundation sequences from the flood animations.
4. Development of a GIS vector database containing evacuation information.
5. Development of response protocols.
6. Development of a flood damage model.
7. Batched flood modelling and mapping process.
8. Evacuation modelling (currently under development).

The Gold Coast City Council is also supporting a CSIRO research project for predictive severe weather modelling that will extend the warning time. Additionally, raising of an additional water supply dam will attenuate and delay flood flows, providing more time for evacuation.

Source: The Hawke Centre.

inter-agency initiative. The Department of Justice has responsibility for domestic counter-terrorism and law enforcement, with the FBI in a lead role. Its mandate from PDD63 is to set up a National Infrastructure Protection Center, with representatives from the FBI, the Department of Defense, the Department of Energy and Transportation, the intelligence community and the private sector, in what is an unprecedented attempt at information sharing. Within the Department of Defense, the Defense Advanced Research Projects Agency (DARPA), the Defense Information Systems Agency (DISA) and the National Security Agency (NSA) are joining forces to design a next-generation information infrastructure. Their scope ranges from policy management tools for network configuration to full nationwide strategic cyber-defence. Finally, the Department of Commerce sets time-bound goals for advancing infrastructure protection and securing information systems – significantly, pulling in the private sector to co-operate on policy formulation.

Other national initiatives to protect critical infrastructures involving the public and private sectors can be found in many OECD countries. Information Sharing and Analysis Centers (ISAC), born of partnerships to address Y2K issues, exist in the United States (where there are individual ISACs for specific key infrastructure sectors – energy, transportation, communications and information technology, finance) and are under discussion in other countries such as the United Kingdom and Japan. Japan also has a co-operative forum (Japan Network Security Association) that brings together a wide range of firms involved in network security – technology providers, network integrators, and Internet Service Providers (ISPs).

At international level, co-operation comes in varying degrees of depth and intensity, ranging from mere agreement on reporting practices, through guidelines on surveillance, to harmonisation of regulations and standards. An interesting example is the Performance Evaluation Guidelines (PEG), developed by a consortium of companies on behalf of the European Commission and drawn up in the context of the enlargement process. A cornerstone of the Commission's strategy on nuclear safety is to bring the general standard of nuclear safety in pre-accession Central and Eastern European countries up to EU levels. The PEG provide a framework for a complete and accurate overview of the status of nuclear safety in countries with nuclear power plants in operation. The main objective is to provide a common format and general guidance to allow for consistent and comprehensive evaluation of plants built to different standards, treating all countries equally. The focus of the PEG evaluation is on plant design, plant operation, the practice of performing safety assessment, and nuclear legislation and regulation.

Infectious disease surveillance is a further area demanding strong international collaboration. Epidemiological surveillance and control of communicable diseases in the European Community, for example, received a substantial boost in the late 1990s with the introduction of a legal framework for establishing a network to provide early warning and response as well as epidemiological monitoring. Early warning and response operates through a telematic link providing public health authorities of the EU and the Commission with an efficient and rapid exchange of information on outbreaks or potential outbreaks of communicable diseases. The surveillance function operates through networks targeted specifically and individually to 41 diseases or special health areas. The reporting requirements apply to the resurgence of all cases of communicable diseases, to the progression of epidemics or unusual epidemic phenomena, and to communicable diseases of new or unknown origin. It is this forward-looking dimension of the network that has triggered debate over the potential usefulness of such a system for, *e.g.,* internationally-based xenotransplantation surveillance – for which no structures currently exist (OECD, 2001a).

In a few areas of prevention, international initiatives have gone all the way to convergence of legislation and standards. Food safety is a case in point, where today substantial progress has been made towards the global harmonisation of regulations. The Codex Alimentarius Commission (CAC), an intergovernmental body operating under the auspices of the FAO and WHO, has so far established around 237 commodity food standards and 41 codes of hygienic practice, and has evaluated some 54 veterinary drugs, 185 pesticides and 1 005 food additives. It has also established Maximum Residue Limits for over 3 000 pesticides, in addition to providing guidance on food labelling, nutrition, sampling and analysis, and import and export certification (Motarjemi, vanSchothorst and Käferstein, 2001).

3. Framework conditions of prevention

Risk prevention involves all levels of decision making in society, from central and local governments where laws and regulations are determined, to corporations in their operations management and citizens in their everyday lives. The overall performance of society in managing risks is determined not only by specific measures of protection, but also by its "risk culture", *i.e.* by attitudes towards risk and safety at every level of decision making. The risk culture is shaped by a variety of practices, norms and laws, including how "acceptable" risk attitudes are defined; how safety regulations are implemented and enforced; risk-related incentives resulting from taxes and subsidies, tort and liability laws, and insurance schemes; and the availability of information on risks.

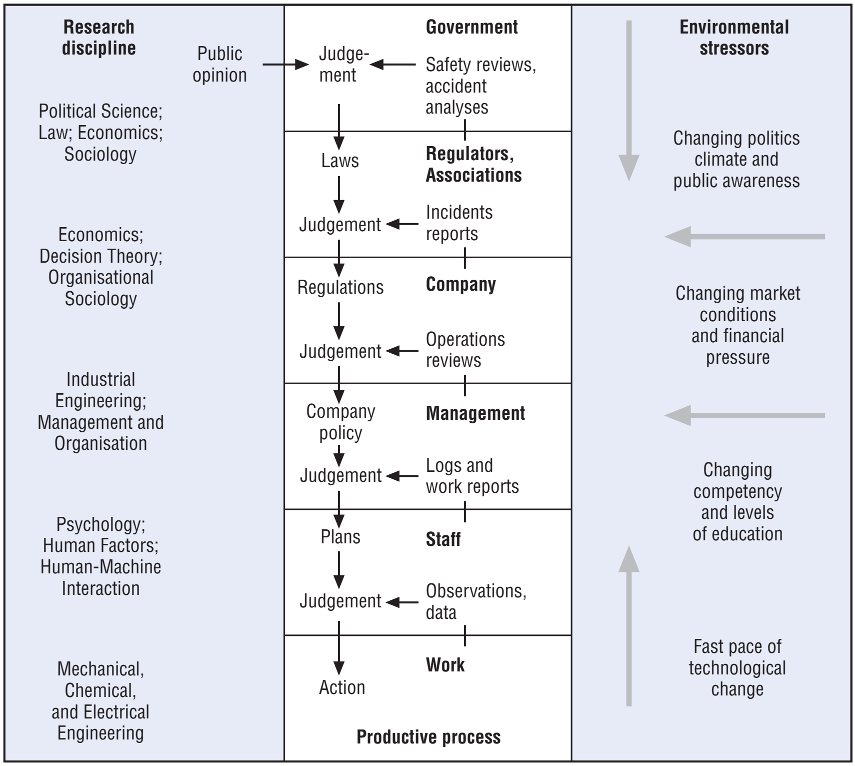
Figure 1, taken from Rasmussen (2001), shows for instance how choices made at different levels of organisation, each influenced by specific environmental conditions, finally combine to affect security inside a technical system. One interesting point is that each level is usually scrutinised by a different research discipline, which makes it difficult to adopt a holistic point of view on safety.

The aim of this section is to analyse how ongoing evolutions change framework conditions and influence "risk culture" in OECD countries; to identify issues that might result for emerging systemic risks; and to explore possible responses.

The present situation

Various options are available for managing risks in society, ranging from the more centralised command-and-control methods to decentralised self-regulation. Each of these strategies has its own strengths, weaknesses and organisational needs, in particular with respect to ensuring enforcement (Hood *et alia,* 1999). Each is adapted to specific conditions, depending notably on the severity of risk (*e.g.* if large and irreversible damage is feared), the ability of individual agents to take account of all dimensions of risk and ensure compliance (in other words, the magnitude of externalities), the knowledge of risks, and the likely reaction of stakeholders. Indeed, a

Figure 1. **The control of productive work processes**



Source: Rasmussen, 2001.

fundamental efficiency criterion for any risk prevention strategy is how it will be received and perceived by the different actors in society, and how they will respond to it in accordance with their objectives and their possibilities.

Although framework conditions vary widely from one country and one risk area to another, they are currently dominated by a number of general developments, in particular the loss of effectiveness of centralised modes of risk management, a trend increase in liabilities, and the involvement of individual responsibilities in the wake of an accident.

The loss of effectiveness of centralised modes of risk management

The driving forces described in Chapter 1 widen the range of choices individuals (and corporations) are offered, increase their mobility, and modify the way they live and work. In terms of safety, one important consequence of these changes is that in numerous cases, the most centralised modes of risk management are becoming less effective.

In large industrial installations for instance, prevention methods usually have emphasised command-and-control and individual compliance to rules. The system's activity is broken down into tasks, seen as sequences of decisions, actions and possibly errors, and rules and instructions are designed for each particular task. A major weakness of this approach, repeatedly underlined by experts (Perrow, 1984, Rasmussen, 1993), resides in a conceptualisation of safety that is divorced from the real work flow, often understating the actual complexity of work situations. As a result, and as was underlined in the previous chapter, individual responsibilities tend to be overestimated in analyses of the causes of accidents.

This weakness has been aggravated by technological and organisational changes under way in the corporate sector of OECD countries for at least the past decade. Already in 1988, referring to the rise of information technology in organisations, two authors evoked the notion of "second generation management applied to fifth generation technology" (Savage and Appleton, 1988). Since then, exploiting the potential offered by new technologies has been the leitmotiv of organisational changes; these promote enlarged responsibilities and multiple competencies for workers, just-in-time production, and network relations. But as decision making has becomes less centralised, interdependencies and time constraints have tightened. In terms of safety, both the number of possible sources of failure and the cost of ensuring compliance to the rules at each source have increased exponentially.

Generally, direct intervention through safety regulations and other command-and-control schemes is only appropriate when government has a better knowledge of risk than other actors. Centralised risk prevention strategies are increasingly faced with the difficulty of monitoring all decisions and actions inside a complex system, as well as with the tendency of individuals and organisations to preserve degrees of freedom. In OECD countries, individuals, corporations and local authorities are every day faced with new risk situations that they have to manage without the help of formal instructions.

Broadening liability and the search for blame

The blunting of command-and-control methods enhances the role of more decentralised tools of risk prevention, in particular tort law and insurance. In effect, liability, compensation and insurance systems have two broad goals: creating optimal *ex ante* incentives with regard to attitudes towards risk (see Methodology Box 1), and providing *ex post* redress to the victims. This chapter is mainly concerned with *ex ante* incentive issues; Chapter 5 adopts a broader view on liability, compensation and insurance issues, including considerations on *ex post* victim compensation.

Methodology Box 1. **Some economic aspects of tort law and insurance**

Tort law determines both compensation and liability related to an accident, at least in cases where a party can be held responsible for damage. In other words, it aims at answering two general questions arising after the disaster occurs: how is the loss endured by the victims to be compensated? How can responsibilities be measured to determine who has to provide compensation? Tort law is intertwined with insurance mechanisms, which can also provide compensation to victims regardless of liabilities (first-party insurance) and cover injurers' liability (third-party coverage).

Issues of liability, compensation and insurance at the same time involve equity and efficiency considerations. Equity issues include measuring the cost of pain and the value of life, allowing them to be different for different people or not, granting available, affordable insurance for everyone, etc. Efficiency, as considered by standard economic theory, relates to the optimality of incentives for risk prevention induced *ex ante* by liability laws and insurance schemes. When a party (potential injurer or victim) can exert an influence on the outcome of a disaster, their liability or compensation prospects as well as insurance policy conditions have to account for the social costs of damage. From the point of view of society, internalisation of social costs leads to optimal private decisions and optimal deterrence of risk-generating activities.

An important issue in this respect is the influence insurance schemes exert on attitudes towards risk. Moral hazard refers to the change of behaviour of the insured party, induced by insurance. In extreme cases, if the cost of risk-taking is totally removed from the insured party, he becomes indifferent to risk. This can be particularly problematic for liability insurance, which then no longer creates incentives in favour of risk prevention, and becomes a mere compensation instrument. The control of moral hazard in liability insurance is therefore crucial not only for the insurer, but for society at large. It requires either a differentiation of policy conditions according to behaviour (either *ex ante*, through a screening of individual profiles, or *ex post*, based on individual loss experience), or, as a second best, exposure of the insured party to risk (through either a deductible or an upper limit of coverage). Such solutions, however, can have limits in terms of equity if they amount to limiting insurance availability.

Naturally, various regimes determining liabilities and compensations for a particular type of risk have to be compared according to their capacity to deal with both equity and efficiency issues in the specific conditions of that risk.

Recent years have witnessed a general trend toward increasing liability in OECD countries. This is principally the consequence of a shift from the concept of negligence to strict liability, of the introduction of elements of retroactivity in tort law, and of a transfer of the risk of causal uncertainty to operators and producers (*i.e.* in cases where the cause of harm cannot be clearly established, operators and producers are held liable more often than before). Such changes seem to respond to the desire to improve victims' compensation; there is a general shift in case law towards increased protection of individuals. In parallel, insurance coverage has steadily shifted from first-party (direct) to third-party (liability) insurance.

In addition to changes in the legal framework, liability exposure is enhanced by more frequent appeals to the tort system, which may suggest the development of a "claim culture". Partly as a consequence, accidents are often followed by a search for those who are to blame, be they firms (in isolation from their partners, contractors, or competitors) or individuals (isolated in a decision-making chain). The emphasis on individual faults might, again, mask organisational and systemic factors contributing to damage.

Some argue that recent evolutions in tort law and social security and the rise of a claim culture tend to reinforce each other (Faure and Hartlief, 2002). As social security reforms and privatisation of insurance lead to a decrease in the compensation ratio (with, among other aims, that of at controlling moral hazard), tort law is called on to play a more prominent role in compensation: individuals more often have recourse to it in claims for compensation, and the judiciary tends to expand the scope of liability in order to improve victim protection. The claim culture among individuals is also encouraged by the supply of services such as insurance polices for legal fees (or similarly contingency fees charged by law firms).

Challenges

Many ongoing developments serve to enhance the role and responsibilities of corporate managers, operators, local administrators and even lay people in risk prevention. As discussed in the previous section, a decentralisation of certain aspects might prove more adapted to the needs of modern societies than traditional top-down strategies. However, a prerequisite is that capacities of and commitment to risk prevention are in line with the increase in responsibilities. Particular attention will be paid in this section to provision of information and to economic and legal incentives. Several major challenges are identified: promoting risk awareness among decision makers and the general public; ensuring commitment to risk prevention in the private as well as the public sector, each in the face of their own operational constraints; improving the use of tort law; and effectively implementing and enforcing preventive measures.

Risk awareness and preparedness

Awareness is vital to the efficient management of risks in a decentralised society. Promoting risk awareness means ensuring that the variety of actors in society understand the different facets, that a particular aspect is not neglected or another overemphasised. It is therefore a matter of exchange and dialogue between risk managers and local actors.

At the corporate level, risk awareness entails identifying hazard sources, potential damage, control requirements and means, and the decision makers for each particular risk situation.

The magnitude of safety margins may well be influenced by a variety of decision makers, from operators to local planners. In the absence of shared information, a natural tendency for each decision maker will be to overstate available margins, resulting in an unwarranted level of exposure to risk. When, by contrast, decision makers later cover themselves against blame, safety margins will tend to be underestimated. There is thus a need to keep every decision maker permanently aware of available safety margins in the system. To use Rasmussen's phrase (2001), the "boundary of acceptable performance" must be made visible to all. Information must therefore be shared as much as possible in real time, to provide feedback on the safety implications of any important decision. Creating the appropriate information channels represents a more or less difficult challenge according to the sectors. It is, however, crucial that risk analysis be kept live and adapted to operational situations.

One major issue regarding provision of information on the sources of risks is the dilemma between striving for transparency and reporting obligations on one hand, and confidentiality and privacy rights on the other. In a context of commercial competition, the necessity of keeping strategic information secret can be a major impediment to transparency on safety issues and an important factor of risk aggravation, as illustrated in the next section.

In many risk areas, from floods to neglected infectious diseases, the public itself needs to be better informed – or updated – on hazard, on means of avoiding it or mitigating its consequences, and on individual responsibilities in risk prevention. Often the apparent lack of commitment to risk prevention among the public actually hides a lack of information. The media, schools, hospitals, local public authorities and non-governmental organisations can play important roles in this respect.

This in turn requires that information be continuously accessible to and usable by local risk managers and authorities, who are not necessarily risk assessment experts. In particular, promising technological tools such as remote sensors or satellite observation (see Illustration Box 3) should be geared to the needs of actors who are faced with risk.

Illustration Box 3. **Charter on Co-operation to Achieve the Co-ordinated Use of Space Facilities in the Event of Natural or Technological Disasters**

The European Space Agency (ESA) and the French Space Agency [Centre National d'Etudes Spatiales (CNES)] signed a Charter in June 2000 to promote co-operation among space system operators in deploying their systems in the event of major natural or technological disasters. The Canadian Space Agency (CSA) joined the Charter in October 2000, and the Indian Space Research Organisation (ISRO) and the US National Oceanic and Atmospheric Administration (NOAA) in September 2001. The objectives are twofold. First, during periods of crisis, supply data critical for anticipating and managing further crises to states or communities whose population, activities or property are exposed to imminent risk, or are already victims, of natural or technological disasters. Second, using data, information and services resulting from the exploitation of space facilities, help organise emergency assistance or reconstruction and subsequent operations.

The parties to the Charter undertake to maintain an up-to-date list of the available facilities under their management and, to the extent possible, space facilities under the management of private or public operators as may be called upon to supplement the parties' own. Moreover, the parties undertake to analyse in concert recent crises for which space facilities could have provided or did provide effective assistance to the authorities and rescue services concerned, and to prepare a report highlighting possible contributions by existing facilities.

It is also envisaged that for each type of crisis identified, scenarios will be designed and proposed that state the conditions under which the parties would co-ordinate their action in supplying appropriate information and services as well as enabling access to the available space facilities. These scenarios, regularly updated, would constitute the basis for action in the event a crisis is identified.

In 2001 the Charter was activated for the following disasters: flooding (4 times), earthquake (3), oil spill (3), volcanic eruption (2).

Source: ESA and CNES.

Commitment to risk prevention and the search for cost-effectiveness

A particularly challenging issue is to ensure that the search for cost-effectiveness and profitability is not detrimental to safety. Although competitiveness and safety are positively related in the long term, maintaining safety margins might often appear in the short term as a dead-weight in terms of time and costs, entailing a loss of resource efficiency. An increase in competitive pressure can then trigger a reduction in safety expenses, and ultimately a deterioration in safety performance. Such a risk can be particularly serious in various public utilities sectors, where competitive pressures and the search for profitability have intensified in past years as a result of deregulation and privatisation. These sectors include telecommunications, distribution of electricity, gas and water, as well as air and railway transportation.

Various channels leading to a reduction in safety have already been documented (for instance, concerning the nuclear industry, see Case Study 2). It has been argued, for instance, that the choice of outsourcing maintenance and other routine tasks was a primary cause of the safety problems experienced by Railtrack, the British rail infrastructure operator (Martin, 2001). Meanwhile, nonreporting of safety problems, inadequate communication, and even commercial conflict between companies and operators have been found at the origin of roll-on/roll-off ferry accidents and supertanker accidents (Shell, 1992).

Commitment to risk prevention in the government

Full commitment to risk prevention is also a challenge for governments and public services. Faced with fiscal constraints, public administrations have in the past sometimes failed to keep safety programmes high on their priority list. Persistent budget restrictions in infrastructure investments and sanitary expenses, as well as lack of training or preparedness of public managers, have been invoked in various cases of aggravated vulnerability to major risks, in developing as well as OECD countries (see Methodology Box 4).

In addition, tax systems and subsidies in numerous cases do not create the warranted incentives for risk prevention. A recent study estimates that OECD countries alone spend more than USD 700 billion every year in subsidies, many of which have substantial harmful impacts on the environment (Pearce, 2002).

Public expenditures and services in agriculture have been found to have an important impact on farming practices and the development of animal diseases, with important sanitary and economic consequences. Subsidies in Europe have encouraged intensive farming with less-than-sufficient consideration for safety conditions. Also, in various Asian and African countries, privatisation of veterinary services has been accompanied by the dismantling of public sanitary services. On the positive side, the public sector has effectively involved private actors, in particular farmers and traders, in disease surveillance and control in several Latin American countries, resulting in an improvement in regulation and supervision (Rweyemamu and Hoffman, 2001).

Illustration Box 4. **Walkerton's E.coli outbreak**

In May 2000, a storm washed bacteria-laden cow manure into a poorly planned and maintained well in Ontario, Canada. In addition, the chlorinator failed, and infected water was pumped to taps throughout the town of Walkerton. This resulted in seven fatalities and 2 300 cases of illness from a virulent strain of E.coli.

A public judicial inquiry ordered by the Premier of Ontario attempted to identify the origins of the incidents, to clarify the role the government had played and to examine overall water safety in Ontario. The investigation first attributed a large part of the responsibility to the longtime manager of the Public Utilities Commission in Walkerton, who had not informed authorities that the town's water was contaminated with E.coli and who routinely falsified water sample tests and records. The manager put forward his lack of proper educational background in court.

Gradually, however, investigation findings pointed also towards organisational failures. The Public Utilities Commission had been informed of bacterial contamination by a fax on 18 May, but had not transmitted information to the Health Office. By the time the Walkerton Medical Officer of Health finally issued a boil-water advisory, three days had passed. In addition, the investigation showed that, unbeknownst to the Commission, the chlorination system suffered from chronic failure.

More broadly, attention was attracted to the fact that since 1995, Ontario's Ministry of the Environment had experienced a 50% cut in its budget. A study following the accident showed that the managers of waterworks networks in some of the smaller municipalities like Walkerton suffered from a serious lack of training.

These circumstances led all levels of government, provincial as well as municipal, to re-evaluate the impacts of their environmental legislation on public health. The Federal Ministry of the Environment intends to guide the elaboration of stricter guidelines on water quality while pursuing scientific research in this domain. The Drinking Water Protection Regulation of the Province of Ontario came into effect in August 2000. This new regulation introduced tough standards and health parameters (such as microbiological parameters, turbidity, chlorine residuals and volatile organics) for drinking water quality under the Ontario Water Resources Act. Large waterworks must meet minimum treatment requirements, have their drinking water tested by an accredited laboratory, immediately notify the proper authorities of adverse test results, and post notice signs to alert the public where water is untested or unsafe. Among other requirements, the owner/operator of waterworks must prepare and submit quarterly consumer reports to the Ministry of the Environment, make these available to consumers, and ensure

Illustration Box 4. **Walkerton's E.coli outbreak** *(cont.)*

that only licensed staff or accredited labs perform tests on drinking water. Finally, the government of Ontario has spent CAD 15 million on reconstructing the town's water system and installing filtration. Justice Dennis O'Connor issued a report of the Walkerton Inquiry with a total of 121 specific recommendations; the Government of Ontario has committed to implementing all of them.

The tort and insurance system

Finally, lack of commitment to risk prevention can also be the result of inadequate incentives induced by liability and compensation regimes.

On one hand, the increase in liability – in particular, widespread application of strict liability – could lead to over-deterrence of some risk-generating activities unless third-party insurance is available. On the other hand, third-party insurance is more exposed to moral hazard issues than direct insurance, since the decisions and behaviour that could potentially lead to liability are difficult to control for an insurance company. In such a case, moral hazard would lead to under-deterrence of risk-generating activities.

One important aspect of the broadening of liability is the retroactive application of new standards, as observed in the United Kingdom's Environment Act 1995 concerning the restoration of contaminated sites, or in some aspects of the US Superfund regime. Such retroactivity seems to violate one of the fundamental principles of tort law, namely that the prospect of liability should create *ex ante* incentives in favour of prevention. This is one of the most powerful arguments against applications of retroactivity, such as the so-called development risk whereby a producer could be held liable for damage caused by its past activity even if that activity did not appear wrongful at the time. By contrast, some refer to the threat of unlimited liabilities imposed retroactively on firms having commercialised a product that subsequently appears to be harmful.

However, at a time when technologies are evolving at a very fast pace – notably in the area of life sciences – it is difficult to ignore the existence of serious potential risks related to the development of new products and techniques, and the need to rely on sound incentives to manage those risks. In such a context, some argue that retroactivity can hardly be ruled out, and that what is essential is a clear framework for managing uncertain risks. According to this view, as long as the possibility of retroactive application of liability in a given area is clearly stated *ex ante* (as, for instance, in the UK Environment

Act 1995), incentives exist – but are simply extended from the area of known risks to that of potential risks.

Recent developments may ultimately lead to an extensive use of tort law and insurance as mechanisms of financial transfer aimed at providing compensation. Compensation has partially been improved at the cost of a blurring of the concepts of fault and negligence. Such an evolution, if continued, would be harmful for the preventive functions of tort law and insurance (see Chapter 5).

Implementation and enforcement of preventive measures

As a result of the changing nature of regulations, local authorities and corporation management have more leeway when it comes to the practical definition and implementation of safety goals and norms.

The European Commission Directive "Seveso II" relative to the control of major accident hazards involving dangerous substances provides an illustration. The Directive explicitly requires that public authorities define a safety zone around industrial installations of concern, and strictly control land use inside these zones; that safety reports and emergency plans (both internal and external) are produced and frequently updated by management, under the supervision of regulatory authorities; that installations are inspected and their safety performance investigated at least once a year, with a follow-up when necessary; and that pertinent information is communicated to the public. However, the precise modalities of implementation and enforcement of the Directive are left to firms' management and national authorities.

The September 2001 accident in the Grande Paroisse plant at Toulouse showed that in some cases this implementation and enforcement gap is simply not filled. At the time of the accident, France had already transposed the European Directive to its national legislation, and made compliance mandatory for industrial plants by February 2001. However, primary investigations showed that the new regulations were based on an oversimplified interpretation of the Directive. The security area defined by regulatory authorities was approximately six times smaller than the zone of severe damage due to the explosion. Land use planning inside this area had remained lax during the past years. Inspections had failed to detect and correct the eventual sources of safety failure. The first investigation report published by the French Ministry of the Environment notably brings under criticism the lack of resources of investigation services, which "forces them to make priority choices in the very installations that have priority" (Ministère de l'Aménagement du Territoire et de l'Environnement, 2001).

Another example of implementation and enforcement issues is furnished by seismic building codes. Substantial progress has been made in the past decade in improving seismic design techniques and building code elements. At least as important, however, is the backfitting of existing buildings. Even in OECD countries, a large share of buildings have not benefited from modern seismic design. In the United States for instance, outside California many earthquake-endangered states had no seismic safety provisions in their building codes or land use plans until recently (Nigg, 1997). In Europe too, a large number of old buildings are not protected by codes. Effectively implementing and ensuring compliance would lead to a substantial reduction of vulnerability to earthquakes in many OECD countries.

Emerging responses

Adapting the targets and means of risk prevention to such rapidly changing issues is, in each risk area, a specific and often difficult challenge that mobilises risk managers as well as regulatory authorities. The immense task of ensuring the international financial system's security in the face of rapidly changing market conditions is one example. A series of cross-cutting solutions are nevertheless emerging.

Building synergies into risk prevention: a public/private toolbox

Numerous opportunities for improving risk prevention are offered by combined public/private approaches. From the collectivity's point of view, it is justified to subsidise loss mitigation expenses as soon as an equivalent amount is saved in public emergency and recovery expenditures. Such subsidies are necessary, even from an efficiency viewpoint, for the part of the population that cannot afford the expenses personally.

One possibility, for instance, is to create funds financed jointly by the private sector and the government with the aim of promoting risk prevention in specific areas or industries. Such a scheme was suggested by the French Parliament after the Grande Paroisse chemical plant accident in 2001, and is currently under consideration. The fund would improve the handling of industrial risk in inhabited areas by assisting industries in their efforts to reduce risk, and by furnishing the means to purchase threatened properties when their owners wish to sell them.

Public/private co-operation can also aim at creating win-win situations with regard to risk prevention. For instance, insurers can require, at least as a minimum condition for providing coverage, that safety rules and regulations are respected. By doing so, they benefit from the scale economies of a common system of norms and standards. In turn, regulatory authorities can rely on the insurance sector for enforcement. For example, insurance companies and other financial institutions could play a major role in the implementation and enforcement of norms such as building codes. Insurance coverage or mortgages could be made conditional on inspection, certification and, when necessary, the adoption of loss mitigation measures (Kunreuther, 1997).

Another example is provided by the impact of ISO certification on the implementation of safety measures in corporations. Such public/private co-operations can be effective risk management tools, complemented when needed by liability law. For instance, an injurer can be held liable for damage even while complying with safety norms if the optimal level of care cannot be imposed through norms.

The Turkish Catastrophic Insurance Pool, created after Turkey's 1999 earthquake disaster, illustrates how the combination of legislative measures (making insurance compulsory), public service (providing insurance up to a ceiling) and market forces (complementary insurance, reinsurance of the pool, possibly issuance of catastrophe bonds) can create the appropriate mix of regulation and incentive to better address risks. It is expected that the TCIP will help significantly improve enforcement of building codes and both prevention and coverage of earthquake risks in Turkey (OECD, 2001s).

Maintaining regulatory effectiveness in a competitive environment

Governments have gradually come up with responses to the challenges of regulating safety in hazardous industries operating in a competitive environment. Regulation of railway safety in the United Kingdom can provide an illustration.

The safety issues that arose in recent years with regard to British railways were found to be in part related to the complexity of the system following the 1992 privatisation: the operator Railtrack, the public regulatory authority, and some 25 contractors were all involved in safety management. Respective tasks and accountabilities were not clearly defined, and the share of risk and liabilities among participants was blurred (Health and Safety Executive, 2002).

This observation led to a programme of reform of the system, aimed at enabling the operator to address competitive challenges without their impinging on safety provisions. The proposed measures have a twofold agenda: first, simplifying and enhancing contracts between the operator and the regulatory authority (network licences), and between the operator and contractors (track access agreements), relying on an efficient liability regime; secondly, modifying franchising conditions for train operating companies, notably by extending the duration of franchises to 20 years in order to improve companies' incentives to invest in safety.

Regulatory reforms aimed at enhancing safety considerations, in particular in recently privatised utilities, share two principal features: they better define responsibilities and make larger use of tort law to create the adequate incentives; and they aim at stabilising the operators' environment and lengthening their time horizon in order to shift safety expenses from a cost factor to an element of competitiveness.

International co-operation and harmonisation of safety codes and standards

International co-ordination and co-operation can go a long way in promoting risk prevention and advancing harmonisation of safety standards when needed. One model of successful co-ordination is finance, which was among the first industries confronted with risks of a systemic nature spreading well beyond national boundaries, due to interdependence among financial institutions. In response, a number of international initiatives have been developed over the years to strengthen the global financial infrastructure and avoid the international spreading of shocks, ranging from mandatory norms to codes of good practice, under the supervision of national central banks and of the Bank for International Settlements (BIS). International organisations such as the International Monetary Fund and the World Bank play a key role in the actual implementation of these standards, codes and practices, which they use as benchmarks.

Concerning the interbank payment systems, for example, the BIS recently issued a set of core principles aimed at reinforcing the safety of those systems that have the greatest systemic importance (*e.g.* netting systems which handle large amounts of money). The principles provide guidance for central banks and international organisations in three major directions: soundness of the legal environment and clarity of regulatory procedures; capacity of multilateral netting systems to cope with the failure of one or more debtors; and integration of risk prevention in the daily operations of important payment systems, from training of staff to selection of operators and transparency. The principles are formulated with sufficient flexibility to fit every national system.

Another example is the activity of the International Maritime Organisation in the field of oil spills, from the SOLAS Convention (1974) and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (1978), to the recent International Management Code for the Safe Operation of Ships and for Pollution Prevention (the ISM Code, that became mandatory in 1998). The ISM, which sets out international standards to ensure safety at sea and the prevention of human injury, loss of life, and damage to the marine environment and property, became mandatory first for tankers, passenger ships and bulk carriers, and then for most ships trading internationally. Evidence so far suggests that the ISM implementation has had a positive effect and the Code is beginning to achieve its aim of creating a culture of safety within shipping companies throughout the world. Finally, in response to the new threats of terrorism, the IMO is currently issuing the International Ship and Port Facility Security (ISPS) code, a new set of international standards for ship security. The code is expected to become mandatory for most ships by 1 July 2004.

National governments have a major responsibility in ensuring that existing international regulations are fully implemented, and that the number of substandard ships is gradually reduced.

4. Cross-sectoral lessons

Strengthening the resilience of systems through modification of their "architecture"

Just as important as specific prevention measures that reduce the vulnerability of installations and large-scale objects, are steps taken to strengthen the resilience of systems against major hazards. Whether the system in question is a critical infrastructure at risk from terrorist attack, or a public health system confronted with the resurgence of well-known infectious illnesses or indeed an unknown communicable disease, or an ecological system endangered by pollution, a crucial key to successful management of the risk could well be diversity (*e.g.* of the software in particular networks), and largely decentralised but effective management of the systems themselves.

Private sector co-operation

The political and socioeconomic events of the last two decades have brought changes to economic structures that have important implications for risk prevention. In many countries the state has retreated from direct involvement in economic activity and private companies have taken on operational and management responsibilities previously assumed by governments. Thus the borderline between public and private has continuously had to be redrawn, and there is little indication that this trend is likely to subside in the coming years. The upshot is that private companies are now such an integral part of key sectors as varied as energy, transport, information and communication, and health, that it is inconceivable that they should not be involved to an ever greater extent in risk prevention.

Information and knowledge transfer

Across the full range of risks addressed above, the disparities in terms of prevention capabilities between developed and developing countries is quite

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striking. Given the growing economic, social, cultural and environmental interdependence that currently prevails and is likely to increase in the future, it is vitally important both to share information globally and to transfer information and knowledge to less developed countries. This is a prerequisite not only for improving living conditions in poorer countries, but also for stemming the flow of risks back to the developed countries through such channels as migration, tourism, trade, winds, ocean currents and so on. International co-operation structures helping to deal with such global interdependencies clearly need to be improved.

Decentralisation of prevention and its framework conditions

Risk prevention strategies increasingly need to keep abreast of changes in everyday practices, to respond to the changes observed and to favour reversible choices to the extent possible – in general, to strike a balance between well-enforced regulation and incentives to self-regulation.

Case Study 1 – Flooding

Forward-looking integrated national flood management: the case of the United Kingdom

In the year 2000 the United Kingdom suffered its most extensive flooding on record, with losses totaling around USD 1.5 billion (of which less than half were insured). Recorded rainfall in October and November of that year was the highest for 270 years and caused the flooding of 10 000 properties. The UK Government's Environment Agency launched an enquiry into the lessons to be drawn from the Autumn 2000 floods. In its report, it acknowledged that the event was a significant indicator of the likely impacts of climate change which, the agency estimated, could increase the risk of flooding in parts of the country over the next 75 years by up to 400%. It also acknowledged that in the future, flood risk management would have to consider the possibility of a repetition of similarly extreme events. Partly in response to these developments, the UK Government has set in train a number of initiatives aimed, *inter alia*, at building a stronger, forward-looking dimension into flood prevention and at strengthening integration of flood management approaches.

Already in 1997, the Department of the Environment, Transport and the Regions (DETR) established the UK Climate Impacts Programme with the specific objectives of co-ordinating and integrating a stakeholder-led assessment of the impacts of climate change at the regional and national level, and helping organisations plan for climate change. A key approach within the programme was to develop alternative climate change scenarios that set out different rates of global warming to 2080. Current and future research is using these scenarios not only to evaluate impacts on the natural, commercial and social life in the United Kingdom, but also to identify possible adaptive measures in areas such as water resources, flooding, buildings and infrastructure, agriculture, and planning. In particular, the challenge of dealing with climate change impacts is regarded as a long and sustained process of building adaptive measures into the provision and maintenance of new defences. Within such forward-looking preventive approaches, the DETR considers there is room for precautionary measures. For example:

- Building oversized culverts and bridges on relief channel schemes;
- Designing defence walls with provision for future raising;
- Avoiding the creation of new defended areas (*e.g.* by leaving recreational and other margins in urban areas outside defences so as to provide additional storage/flow capacities.

What is thought to be crucial for the future is the development of a strategic approach to the management of flood and coastal defences. The UK Government has started a new initiative to prepare catchment-wide flood management plans (CFMPs) for all 80 catchments in England and Wales. CFMPs will form a large-scale strategic planning framework for integrated management of flood risks. They are being developed by the Environment Agency on the basis of catchment area assessment studies and will evolve into common guidelines which are currently being finalised and tested on pilot catchments. They will enable flood control measures to be integrated through the use of computer-based models that can be adjusted to allow for future changes in both climate and land use.

Sources: Lessons Learnt – Autumn 2000 Floods, Environment Agency Report, March 2001; "UK Government Response to the Institution of Civil Engineers (ICE) Presidential Commission", 2001; UK Ministry of Agriculture, Fisheries and Food, "Flood and Coastal Defence Project Appraisal Guidance", 2001.

Case Study 2 – Nuclear Accidents

Nuclear regulatory challenges arising from competition in electricity markets

The deregulation of electricity markets has raised various concerns regarding the safety of nuclear power plants (Meshkati and Butler, 1998). In the past, the main economic concern of nuclear safety regulators was to ensure that the utility had a stable source of income to operate the plants safely, including decommissioning and nuclear waste management. The changing context of electricity markets throughout the world, in particular deregulation of and increased competition among utilities in OECD countries, is rapidly modifying this landscape. Nuclear electricity generation involves large fixed costs and low fuel costs compared to generation from fossil fuel plants. As competitive pressures intensify, nuclear operators (increasingly from the private sector) might be inclined to cut costs (through staff reductions, increased reliance on contracting and online maintenance) and/or increase production (through generation capacity upgrading, increase of capacity factors, and extension of the life of plants) at the expense of safety.

More specifically, four categories of challenges might arise (OECD-NEA, 2001):

- *Governance issues:* dilution of responsibilities for safety as a result of changing ownership or leasing of portions of nuclear sites; decoupling of owners and top managers from technical managers; widespread use of contractors to a point where it might become detrimental to the operator's ability to understand, control and effectively manage the system; insufficient funding for decommissioning and waste management.
- *Direct safety issues:* loss of focus on safety among the management; worker fatigue and stress resulting in particular in an underreporting of safety problems; lower quality of work; reduced maintenance and investment in equipment upgrades and safety backfits, and plant ageing problems; reduced safety margins, including power upgrades and increased fuel burn-up; reduced preventive maintenance in favour of online maintenance; decreased grid stability and reliability.
- *Technology infrastructure issues:* loss of expertise in the broader nuclear industry, including universities; loss of design basis knowledge; reduced co-operation among operators; reduced safety research by operators, and pressure to reduce regulatory safety research.
- *Pressures on the regulatory body:* need for new regulatory competencies, in particular in order to understand and follow market conditions; less expertise available; less co-operation with operators, including reduced access to sensitive market information; diminishing legislative enforcement possibilities; pressure to reduce regulatory impact costs, as well as perceived unnecessary regulatory burdens, and to avoid requiring shutdown; need for international consistency of regulations.

Case Study 3 – Infectious Diseases

Preventive strategies against infectious diseases

International strategies to combat infectious diseases have undergone important changes in recent years. The long-standing traditional approaches to containing outbreaks were essentially defensive in nature (brick wall methods) which tried to secure borders against invasion by emerging infectious diseases. More innovative approaches are now in use; these consist of early warning surveillance systems, plans for epidemic preparedness, stockpiles of vital medicines and materials, and communication and sharing of information through networks. Under the framework of the International Health Regulations, for example, WHO – together with its partners – is committed to the systematic collection of epidemic intelligence, rapid verification and the co-ordination of international response. It is in daily contact with its 191 member states, and every year around 200 outbreaks of potential international importance (*e.g.* cholera, meningitis, haemorrhagic fevers, anthrax) are actively verified.

In 2000, WHO initiated the Global Outbreak Alert and Response Network, which links more than 72 existing networks and institutions around the world, many of which are equipped to diagnose unusual agents and handle dangerous pathogens. The Network has four main tasks: epidemic intelligence and detection; verification of rumours and reports; immediate alert; and rapid response. It has already launched several effective international responses to outbreaks in countries as diverse as Afghanistan, Kosova, Saudi Arabia and Bangladesh.

New threats are emerging in the form of antimicrobial resistance. A large number of pathogens have gradually developed resistance to first-line and then to more advanced antimicrobials, through an inevitable process of natural selection. These include in particular agents responsible for pneumonia, dysentery, cholera, typhoid, AIDS, malaria, hospital-acquired "super infections" such as salmonella and staphylococcus aureus, and gonorrhoea. A growing number of typhus infections in India are becoming resistant even to recent third-line drugs. Among the factors behind increasing antimicrobial resistance are overprescription and misprescription, use of counterfeit drugs, the excessive use of antibiotics in agriculture, and the undue focus of developed countries on national health objectives which has allowed pathogens to proliferate and mutate outside their borders before bouncing back with increased resistance. This latter point in particular demonstrates how crucial it is to adopt a global perspective on infectious diseases.

In response to these developments, WHO is now developing a Global Strategy for Containment of Antimicrobial Resistance. The strategy provides a framework of interventions designed to slow the emergence and reduce the spread of antimicrobial-resistant micro-organisms through such measures as improving access to and use of appropriate antimicrobials, strengthening surveillance capabilities, and encouraging the development of appropriate new drugs and vaccines.

Finally, in a recent development, several countries are using preparedness plans for an influenza pandemic as the basis of planning for a possible bioterrorist attack, as many issues concerning shortage of vaccine supplies, finite manufacturing capacity, stockpiling of drugs, and surge capacity in hospitals pose similar logistic problems.

Sources: WHO (2000), "Global Outbreak Alert and Response", report of a WHO meeting, Geneva; WHO (2001), "WHO Global Strategy for Containment of Antimicrobial Resistance", Geneva.

Case Study 4 – Terrorism

Protection strategies against terrorism

As terrorism involves many different organisations – each with its specific ideology and goals – and as any of them can use a variety of channels and weapons, there cannot be a single, one-size-fits-all strategy to tackle it.

In many circumstances the terrorist threat is easier to control in its early phases, before the resources it needs have been brought together, than at later stages where an attack becomes possible. Therefore, prevention efforts must first and foremost aim at combating the emergence of terrorism: address its root causes, from ignorance to injustice and political exclusion; attack its infrastructures and financial networks; control its access to sensitive knowledge and material; discourage involvement in terrorist organisations, and weaken their supports and sponsors.

Such strategies, however, can only be effective in the long term. In addition, they cannot address all the significant sources of terrorism, as even a small number of individuals can nowadays cause massive damage through terrorist attacks. As a consequence, it is generally recognised that catastrophic terrorism will continue to be a major threat for OECD countries in the coming years, and that urgent action is needed to decrease society's vulnerability to it. This section focuses on three core elements of protection against terrorism.

Improving co-ordination in surveillance and alert

Early detection and mitigation of attacks is, first, a matter of preparedness. As a large fraction of terrorist acts follow various precursor signals, better collection and analysis of intelligence and communication of the relevant information are crucial (see Case Study 4 in Chapter 2).

Effective surveillance prior to the advent of an attack and early warning constitute a second layer of protection. Experience of catastrophic terrorist actions has consistently shown that surveillance and warning can be dramatically improved by increased co-ordination among international, national and local authorities and private-sector sources.

The detection and evaluation of bioterrorist attacks, for instance, would be more effective if the information collected by practitioners and laboratories monitoring infectious disease outbreaks was transmitted in real time to decision centres. The World Health Organisation – the co-ordinator of the global surveillance system for infectious diseases – is informed of an epidemic outbreak by medical reports and other unofficial sources in 7 cases out of 10, with delays ranging from 1 to 215 days.

Enhancing prevention through partnerships

The private sector has a considerable potential to prevent terrorist risks, which remains largely untapped due to the lack of incentives and resources. Technological and scientific developments are one example: because of limited commercialisation prospects, research and development in many promising areas is below the level needed to make significant inroads into terrorism's capacity to do harm. Some governments have started to address this issue through incentive schemes and public-private partnerships. Canada, for instance, has recently allocated significant resources to the CBRN (Chemical-Biological-Radiological-Nuclear) Research and Technology Initiative which is designed to further science and technology in the field of counter-terrorism by building partnerships among industry, government and academia.

For instance, measurement technologies such as sensors could in the future play a major role in increasing the efficiency of surveillance systems (Committee on Science and Technology for Countering Terrorism, 2002). Providing that some progress is made in the detection of chemical and biological agents, sensors could provide a reliable tool for identifying volatile agents or explosives, testing the safety of the air in air-conditioning systems, etc. They could also provide a solution to the propagation of damage in networks by islanding specific parts of the network (*e.g.* in electric power grids).

Likewise, improving knowledge of major pathogen agents – *inter alia*, by decoding their genome – would lead to more rapid diagnoses better therapeutics and vaccines, and a reduction of the bioterrorist threat. This, however, represents too large a challenge for any single pharmaceutical or biotechnology company. Partnerships between governments and these industries would help foster research and development, co-ordinate and target efforts, and intensify the flow of information from researchers to regulators (Knobler, Mahmoud and Pray, 2002).

Another form of partnership was advocated to fight cyber-terrorism by the United States President's Commission on Critical Infrastructure Protection (1997): cross-sectoral "clearing houses" could bring together industry representatives and state and local government authorities to provide policy advice, implementation commitment and real-time capability for warning. Such clearing houses could serve to promote industry development and implementation of common incident reporting processes; initiate and co-ordinate exercises and simulations (pressure-testing ICT systems) to assist government and industry in risk management decision making; and define security standards for ICT networks and their infrastructural interfaces. They would act as both centres for knowledge transfer on security and streamliners of the regulatory structure, which may not have kept pace with market and technology developments.

Increasing the resilience of social and physical infrastructures

System interdependencies are a prominent feature of risk issues today, particularly in relation to terrorism. Indeed, the very aim of terrorists is to have a systemic impact, so their attacks have the highest possible secondary repercussions – in terms of people affected, economic costs, social disarray and ultimately, political consequences. Interdependencies imply that the failure or disruption of a system will entail costs for other systems. Increasing the resilience of target systems, in particular of critical infrastructures, is therefore crucial to minimising the overall costs of terrorism. The events of 11 September 2001 have provided several precious lessons in this respect.

In the banking industry for instance, where business continuity is usually ensured through backup facilities, it was noticed that quite often these facilities were affected as well as the primary sites. Or, in spite of planning efforts, they were not kept updated, for instance in terms of computer hardware and software. In response, the banking industry in the United States has since tended to reduce concentration and increase diversity. Business continuity plans now integrate the possibility that very broad geographical areas might be affected by a hazard. Increasingly, the idea is that

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two or more operating sites, preferably distant from one another, provide backup for each other; diversification of telecommunications services and methods (wireless, Internet) is encouraged to reduce vulnerability (Ferguson, 2002). And finally, to confirm the importance attached to resilience, the Federal Reserve is considering issuing supervisory guidance and examination procedures for business continuity in financial institutions.

Governments also need to better identify the vital network nodes and elements of critical infrastructures, and develop procedures to insulate them from system disturbances. In the case of information and communication infrastructures, for instance, the interfaces of particular importance are those that connect to high reliability systems such as nuclear and process industries, air traffic control systems, and certain physical distribution systems such as railroads, pipelines and bridges (Hellström, 2001). Critical nodes may also be identified in emerging information-dependent systems, such as Intelligent Transportation Systems (ITSs) which rely on GPS.

Case Study 5 – Food Safety

The food safety system in the United States

Systems for ensuring the safety of food in OECD countries generally come under the joint responsibility of the legislative, executive and judicial branches of government. The respective roles of the branches vary from one country to the other: legislation can be elaborated by the parliament or by governmental departments and agencies, be formulated under different legal forms, and be implemented and enforced through various means. Independently of their institutional organisation, however, food safety systems need to be based on an integrated approach encompassing the various authorities in charge of regulation as well as the food industry and consumers, in order to effectively guarantee an adequate level of protection to citizens. The United States' food safety system provides an illustration of the merits of and challenges facing such an approach.

In the United States, laws aimed at ensuring food safety are enacted by the Congress and implemented and enforced by governmental agencies, which can, if necessary, develop regulations to transpose and adapt legislation. The Food and Drug Administration (FDA) is in charge of preventing unsafe, impure and fraudulently labelled food from reaching customers in food sectors, with several exceptions. Meat, poultry and egg products are supervised by the Food Safety and Inspection Service (FSIS); the Environmental Protection Agency (EPA) ensures health protection from xenobiotics such as pesticides; and the Animal and Plant Health Inspection Service is in charge of protection against plant and animal diseases. Decision making has to be science-based, but contains important elements of precaution. It has to be transparent and open to the public. Food suppliers, from manufacturing to import and retail trade, are held liable for the damage caused by unwholesome food if their lack of compliance with regulations is established. Courts are empowered to settle disputes and attribute liabilities.*

As in many other OECD countries, the US food safety system has been faced with severe challenges in recent years: outbreaks of foodborne illnesses (due to E.coli, salmonella, listeria monocytogenes, etc.); new patterns of consumption; increased product complexity due to new technologies; international regulatory issues regarding food safety; and rising expectations of safety among citizens. Important changes have been introduced in the system in order to address these issues, mainly in two directions: first, more focus on the reduction of pathogens through various risk management strategies; and second, the adoption of a comprehensive prevention strategy encompassing all segments of food supply (the so-called "farm-to-table" approach).

Implementation of hazard analysis and critical control point systems has been the cornerstone of pathogen prevention strategies (on HACCPs, see Case Study 5, Chapter 2). The use of HACCP plans was made compulsory for the seafood industry

* A detailed description of the US food safety system can be found in the OECD Compendium of National Food Safety Systems and Activities (2000).

in 1997, and for meat, poultry and egg processing plants after 1998. In 2001, the FSIS found that meat, poultry and egg plants operating under HACCP systems had a 97.7% compliance rate with regulations (FSIS, 2002). Regulatory authorities are now considering extending this requirement to the whole food industry as an additional safety assurance.

In parallel, performance standards have been extended from ready-to-eat and processed products to raw products. Standards for reduction of specific pathogens have been established, starting with salmonella, and tests have been introduced to ensure that they will be attained by producers. In addition, good practice standards and guidelines have been produced to increase awareness of hygiene and safety issues in all segments of food supply: Good Agricultural Practices are meant to ensure safety from seeding to harvesting of raw materials; Good Manufacturing Practices concern the processing industry; and a Food Code has been developed for retail food activities, with more than a million food establishments (from retail outlets to nursing homes) applying its recommendations.

Adopting a more active strategy of prevention all along the food supply chain implied increasing inspection and enforcement efforts, which had been found inadequate on several occasions in the past, notably concerning imported products.

In 1998 it was estimated that only 59% of food establishments would be inspected within four years. In response, the FDA has prioritised its inspection effort in recent years, with a particular emphasis on "high-risk" and international inspections. In parallel, funding for food safety was steadily increased by Congress, enabling the FDA in 2002 to substantially raise the number of inspections of domestic manufacturers and importers.

Reporting obligations and enforcement authority were also weak. Reporting to inspectors of positive microbial tests – which would provide evidence of sanitary deficiencies in the plant – is not compulsory. In addition, agencies could not require food producers or importers to withhold a product until its safety is established. Recently, federal agencies were given access to company records in cases where they suspected contamination of food, and received authority to detain food in cases of emergency (Thompson, 2001).

Finally, public-private co-operation and partnerships aimed at improving food safety have been enhanced. The government has encouraged self-regulation in parallel to the gradual implementation of HACCP plans. Regulatory authorities are also evaluating the role that standards and certifications (for instance, the ISO-HACCP 9000 standards) might play in the enforcement of regulations. Finally, education programmes for the public have been developed jointly by federal and state governments, industry and academia.

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ISBN 92-64-19947-0
Emerging Systemic Risks in the 21th Century
Emergency Management

Chapter 4

Emergency Management

Abstract. *This chapter is concerned with the response to disaster. It takes a wide, forward-looking view, recognising that an effective response will depend not only on actions immediately prior to, during and in the aftermath of a disaster but also – importantly – on pre-existing plans, structures and arrangements for bringing together the efforts of government and voluntary and private agencies in a comprehensive and co-ordinated way. Since a whole spectrum of emergency needs is involved, such efforts necessarily go well beyond those required to cope with routine emergencies.*

Executive Summary of Chapter 4

Future challenges relative to emergency management and disaster response can be grouped around the following themes: the use and potential of new and emerging technologies; the importance of effective monitoring and surveillance; planning and co-ordination of emergency responses; managing the media; containing damage propagation once disaster has struck; and international co-ordination of emergency operations.

New technologies, in particular high-performance and distributed computing, satellite observation and imagery, mobile communications, and the Internet hold the prospect of significant benefits to emergency management if their potential contributions can be realised. But those employing them face a number of obstacles – uneven distribution and access, availability of the requisite skills, the technologies' systemic vulnerability and lack of reliability in emergencies and, last but not least, their frequent inability to furnish data and information that are comprehensible and usable for practitioners on the ground.

Those and other technologies form part of the world's much enhanced capacity for hazard surveillance. However, despite considerable progress in surveillance structures in areas such as chemical and nuclear hazards, weaknesses remain – particularly when it comes to relatively new systemic risks such as terrorism and emerging infectious diseases. Where surveillance systems for such new risks are based on pre-existing structures that are themselves deficient, the risks and challenges for the future may well be magnified.

Planning and co-ordination of emergency operations pose other issues. First, response to disasters can only be anticipated, and therefore planned, up to a certain point. Yet despite the sheer diversity of disasters, it would seem that certain generic conditions tend to apply that make for more effective responses (e.g. risk awareness within the community, familiarity and regular interaction among the various organisations responsible for emergency operations, trust and confidence in the relevant decision-making authorities, political leadership). Beyond that point, however, effective response depends crucially on the ability of all concerned to react flexibly and in an innovative fashion to the situation as it unfolds. New avenues remain to be explored for enhancing just such capabilities. Second, there are inevitable trade-offs between centralisation and decentralisation of emergency management structures and their operations. In recent years new approaches (e.g. Incident Command Systems) *have surfaced and been adopted. On the whole these tend to deliver better outcomes, but more needs to be known about the conditions and circumstances under which they promote or hinder increased effectiveness of emergency management. Thirdly, new systemic risks such as bio- and cyber-terrorism or new infectious diseases could pose particular challenges to the planning and co-ordination of emergency responses. In part this is because the sheer scale of the disaster may place intolerable strains on the emergency services, incapacitate those involved in the operations and, more fundamentally, call for more innovative approaches to problems of logistical complexity, timeliness of damage containment measures, and so on. In part, however, new risks may also imply higher levels of decision making,* i.e. *at national and international levels.*

The difficulty with the (inevitable) involvement of the media in disasters is that they tend to be a two-edged sword: on the downside, they may converge on the disaster site and hamper emergency operations, contribute to the propagation of disaster myths, or release erroneous reports; on the positive side, they may be essential for disseminating warnings or communicating information on mitigative action. The key with media would appear to be for authorities to build positive relationships in planning and operations at a very early stage, notably the disaster preparedness phase, and have clear and coherent plans for interacting with the media as a disaster unfolds.

In the damage limitation phase, two factors stand out. The first is the continuing assessment of the situation through efficient, dependable information collection and analysis. The second is the resilience of the emergency management systems, organisations and mechanisms to the impact of the disaster, for instance the coping capacities of primary health care or the reliability of mobile communications.

*Finally, as the globalisation process links countries, markets, sectors, people and cultures ever closer together, the co-ordination of disaster response at international level takes on particular importance. Clearly there are still many problems related to matching the international response to the severity of the emergency. Reasons may be poor informational infrastructure or notification, tardy co-ordination of relief operations leading to under-response, unco-ordinated relief measures resulting in over-response, or the absence of guidelines and structures for minimising the disaster spillover effects on other countries. Examples of sectors endowed with internationally applicable instruments can be found, but with few possible exceptions (*e.g. *perhaps the nuclear sector) they tend to cover only part of the full range of emergency management aspects treated here, or are proving difficult to enforce.*

1. Introduction

Broadly defined, the management of emergencies involves anticipating situations that place people's lives, their property or the environment at risk and, once such a situation arises, mitigating adverse impacts to the maximum possible extent, using established available resources together with additional ones that can be marshalled in time to make a difference. Thus, while emergency management as commonly understood focuses on how best to respond once disaster has struck, practitioners increasingly take a wider, systemic view of what is involved. For example, an effective response will largely depend on the availability of pertinent information prior to the disaster, on the ability to communicate effectively with the public and the media, and on pre-existing plans, structures and arrangements to bring together the efforts of government, voluntary and private agencies and the affected community in a comprehensive and co-ordinated way to deal with the whole spectrum of emergency needs. This chapter examines each of these underlying premises in turn, exploring some of the key challenges they give rise to – now and in the future – and reviewing some of the responses beginning to emerge.

Mounting an effective response to a crisis situation can be particularly challenging precisely because disasters are different from routine, daily emergencies. Thus, the US Federal Emergency Management Agency (FEMA 1984) has defined a disaster as:

> The occurrence of a severity and magnitude that normally results in deaths, injuries, and property damage and that cannot be managed through the routine procedures and resources of government. It usually develops suddenly and unexpectedly and requires immediate, co-ordinated, and effective response by multiple government and private sector organisations to meet human needs and speed recovery.

The definition can readily be extended to include systemic impacts of an economic, social or environmental nature.

The difference is more than one of magnitude, of mobilising more people and equipment. From a planning and response point of view, disasters are also qualitatively different. They tend to place communities under extreme stress; demands on those responding to the incident are different; and numerous

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groups, agencies and other organisations involved are often quite unfamiliar with one another (Quarantelli, 1988; see also Table in the Annex).

Society's ability to effectively plan in advance of and deal with disasters is constantly under challenge. Chapter 1 explained factors at work that are changing the risk landscape – decreasing some risks, increasing others, or creating relatively new ones which, like emerging systemic risks, are often hard to grapple with. Both the planned and the unplanned happens, setting off a chain of events which rapidly cripples the very systems that in "normal" circumstances can be counted on to deal with emergency situations. Disasters are thus the ultimate test of emergency preparedness, response and recovery capabilities.

2. Information and data – collection and access

The present situation

Already in the preceding chapters of this report, it was apparent that collection and access to information and data, as well as their most accurate evaluation, are of paramount importance in the identification, assessment and prevention of risk. They are, however, equally important in managing emergencies and bringing about rapid recovery. Before disasters occur, in the period immediately preceding and during the unfolding of the disaster itself, identification of the potential sources of disaster, accurate appraisal of scale and impacts, and knowledge of the human, technical and economic environment in which they occur are all critical for those responsible for planning and managing the crisis and its aftermath. Quality information of this kind, especially when it embodies lessons learned from similar disasters, serves various purposes: it helps to speed up the emergency response; it reduces the likelihood of unpleasant surprises; and it contributes to ensuring the adequacy of the emergency response measures taken.

Naturally, the picture becomes much more complex when a disaster affects more than one country, necessitating co-ordination of information and data to ensure that the emergency response can proceed effectively. Considerable progress has been made in information gathering and sharing for emergency management, thanks largely to the utilisation of risk communication to communities and advances in technology (universally accessible databases, widespread computing and communications capacity and satellite imaging), to institutional co-ordination, and to the establishment of guidelines for information sharing. But in terms of "familiar" natural and technology-related disasters, much remains to be done; and in terms of new, emerging systemic risks such as terrorism, information infrastructure disruption and new infectious diseases, the uncertainties are great and the information and institutional requirements less clear.

The challenges

Technology

A plethora of technologies are already or soon will be available that can provide useful information and data for efficient and effective emergency management. These include imagery from geostationary and low-earth-orbiting satellites (Illustration Box 1), aerial photography, and ultra-sensitive listening devices (*e.g.* for locating trapped people). An increasing volume of such information can be accessed via the Internet. Particular attention in recent years has focused on geographic information systems (GIS) – which make it possible to merge geographic, spatial or locational data on, for example, the scale and extent of a disaster, with information on settlement patterns, buildings (and other infrastructure) and characteristics of the affected population. GIS is used therefore not just for pre-event vulnerability assessment but also for improving preparedness, mitigation and response plan activities.

There are, however, numerous obstacles associated with the implementation of these various technologies, new and old:

- Most obviously perhaps, not all countries have adequate technological capacities, such as a network of satellites at their disposal or even real-time access to satellite data. This has much to do with problems of integrity of communication channels, transparency, and liability issues, but also with resources. GIS systems, for example, can be expensive to operate and maintain, and substantial computing capacity may be needed to analyse large data sets sufficiently quickly and respond to a disaster in a timely fashion.
- There is often a problem of awareness and skills: many local decision makers may not be aware of the potential usefulness of, *e.g.*, satellite images, do not request them, and would not know how to evaluate or apply them even if they had access to such information. This is related to well-established traditions of local emergency managers that lead to a reluctance to explore or adopt new technologies – or conversely, the relatively frequently observed trend of developing emergency management solutions around new technologies rather than exploring ways of integrating new technologies into existing approaches. The products and services available from the spatial information and remote sensing industries do not necessarily meet the requirements of emergency managers.
- There is a tendency to use some new technologies (*e.g.* GIS) more for descriptive and representational purposes than as an aid to decision making.

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Illustration Box 1. **Space monitoring of oil spills**

Oil spill hazard is caused either by tanker break-up at sea, or illegal discharge and tanker clean-up. The former may result in large amounts of oil released in a short time, while the latter is more frequent but involves smaller quantities each time. Many countries have signed regional protective agreements such as MARPOL and UNCLOS, which forbid dumping of waste materials in the marine environment.

Earth Observation data are already used operationally for enforcement and monitoring. The main users are Norwegian Pollution Control Authority (SFT) and the Admiral Danish Fleet. The principal satellite data source is the spaceborne Synthetic Aperture Radar (SAR). Quickly processed low-resolution SAR images are generated over the affected sea area. The information retrieved from the data is used by the pollution control authorities to optimise the flight plan of surveillance aircraft. In some cases high-resolution SAR imagery is obtained for a more detailed observation. SAR images are available on a routine basis since the launch of ERS-1 in 1991, followed by Radarsat, ERS-2 and, in 2002, Envisat, all of which carry SAR instruments suitable for oil slick monitoring.

The interpretation of SAR imagery in the coastal zone of major accidental oil spillage is problematic in view of wind shadows, etc. that have the same effect as the dampening effects of an oil slick. Under these circumstances, more easily interpreted optical data [such as SPOT Visible High Resolution and LANDSAT (TM/ETM)] may be used.

Earth Observation data provide a uniquely cost-effective method for wide area, systematic surveillance of national and regional waters to determine the geographic/seasonal patterns of oil dumping. Such surveys, combined with statistical analysis, may be used to determine both the scale and geographic distribution of the pollution problem.

In the post-spill phase, authorities may be interested in knowing where the oil is likely to come ashore. The space EO data-derived spill vector outlines, which can be integrated with meteorological satellite data and marine current data, may predict the potential beaching zones of the oil. Another space tool for oil spill trajectory prediction is the operational air or ship dropping of Argos drifters (the French location and data collection system on board NOAA satellites) to help accurate tracking of oil slicks (this was tested after the Erika sinking in December 1999 along the French coast). Operational implementation requires identification of adequate response centres in strategic places, several stocks of drifters, and a data distribution mechanism to regularly inform the concerned civil protection authorities.

Source: European Space Agency (ESA); Canadian Space Agency (CSA); Committee on Earth Observation Satellites (CEOS) Disaster Management Support Group Report, and CNES (the French Space Agency).

- Where information and knowledge management is an increasingly strategic tool for decision makers, there is often a greater dependence on computation and communications at the price of new vulnerabilities. Access to new information and communication technologies (ICTs) can be a double-edged sword – potentially invaluable for emergency services in the field, but not always capable of operating dependably when most needed (see Section 4).

Finally, even where there is some degree of familiarity with the intelligence provided by ICTs (*e.g.* the Richter scale for information on earthquakes), that information needs to be combined with other data, such as direct observation, reports from the field, terrain data, satellite imagery, etc. Only in that way can a picture be painted for emergency management decision makers of the extent and seriousness of the specific disaster at hand. All too often, decision makers who are not experts or at least knowledgeable in the interpretation of specific scientific data are unable to use the potentially vital information in a straightforward fashion to assess the damage, and thus the action needed to be taken. Some experts argue that severity scales are required that both convey a sense of the extent of potential damage and are applicable across various types of disaster (perhaps along the lines of the modified Mercalli Intensity Scale).

Information gathering and sharing

Access to and use of reliable information on the ground is crucial to the first stages of disaster response operations, not least because without good intelligence, reactions can be triggered among key decision makers that may be disproportionate to the requirements of the situation. Just as under-response can be highly detrimental to aid and rescue, over-response too can throw unnecessary obstacles in the way of relief operations. A well-known illustration of under-response is Hurricane Andrew, which struck Florida in 1992. Poor information and faulty assessment of the situation by the governor led to significant exacerbation of the damage and prevented the timely intervention of federal services in the immediate post-impact period. Conversely, the quite frequent over-mobilisation of resources can complicate response co-ordination significantly. Particularly prone to the phenomenon of exaggerated reports about the number of disaster victims is the transportation to hospitals. An over-supply of emergency management resources, especially ambulances, is often observed in developed countries' responses to disasters (Quarantelli, 1983).

Moreover, command of modern technology is not in itself always sufficient for an adequate emergency response. Highly specialised and therefore frequently centralised emergency teams that have the knowledge and resources to use sophisticated technologies often encounter considerable difficulties on the ground because of their lack of familiarity with local conditions.

In the international arena, a number of sectors have well-established criteria and procedures for information gathering and sharing. With respect to chemicals, for example, the IPCS, OECD, UNEP and WHO issued a joint manual in 1994 on health aspects of chemical accidents which offers guidance to health professionals and emergency responders with respect to health-related information and communication needs (OECD, 1994). More recently (2002) the OECD – in collaboration with UNEP and the United Nations' Office for the Co-ordination of Humanitarian Affairs (OCHA) – published an International Directory of Emergency Response Centres of Chemical Accidents covering 30 countries. The centres maintain lists of experts and relevant information, and stand ready to share information and/or assistance with government institutions or emergency centres in other countries. Further, since the Chernobyl accident in 1986, considerable progress has been made in the nuclear industry concerning agreed notification procedures (Case Study 2).

But at least two question marks remain for the future, one over the "moral hazard" problem of international public reporting (*i.e.* reluctance to volunteer information that might reflect badly on the country concerned) and the other over the efficiency of international strategies for information gathering and exchange in the area of new, emerging systemic risks such as bio- and cyber-terrorism, or new infectious diseases.

With regard to the first, even where reporting systems are in place, institutional inertia, denial and preoccupation with one's national image can significantly weaken the effectiveness of information exchange and thus the response to a crisis. For example, not all developed countries have a good track record from the 1980s in reporting HIV/AIDS cases. This has improved since, but the problem looks set to repeat itself for some of the major developing countries. China for example reported only 22 517 registered cases in 2000, a figure that one year later was suddenly raised by the Chinese health authorities to around 600 000. The UN AIDS programme, however, estimates that more than one million people in China are infected with HIV, and that the figure could in fact be two or even three million. If unchecked, there could be more than 20 million AIDS sufferers by 2010 (Gill, Chang, Palmer, 2002).

The second question mark hangs over the adequacy of international surveillance of new emerging risks. Remaining in the domain of health, recent history offers numerous reminders of the inherent difficulties in trying to contain the worldwide spread of emerging microbes. The Reston Ebola outbreak among research monkeys in 1989 demonstrated how easily a new and dangerous virus could spread to hundreds or thousands of people on several continents in a very short time, thanks to modern jet transport of animals and lacunae in handling procedures (it eventually proved to be harmless). In the mid-1990s, a survey of 34 disease detection laboratories worldwide, whose task is to alert the global community to the outbreak of dangerous viral diseases, revealed significant inadequacies in skills, equipment and general capabilities. For example, only half of the laboratories were able to diagnose yellow fever (Garrett, 1995). To the extent that current efforts to improve surveillance of new diseases rest largely on making use of existing surveillance networks, a concerted effort to strengthen these also seems to be needed.

Emerging responses

Recent years have seen growing interest in applying advanced technologies hitherto confined to activities like defence and intelligence gathering to the field of disaster management (*e.g.* remote sensing, global positioning satellite systems, synthetic aperture radar systems and high-performance computing). Moreover, existing technologies continue to be enhanced. In GIS, for instance, the HAZUS system – which models earthquakes' direct damage to buildings as well as indirect damage such as fires in their wake – was initially found to under-perform in areas of low seismic activity compared with areas of high seismic activity, and has since undergone considerable refinement.

Further, there have been advances in more straightforward, more generally comprehensible interpretation of vital scientific data relevant to disasters. A major initiative in this field is the Global Disaster Information Network (GDIN), which concentrates on both national and international sharing of data and information for disaster management purposes. Its primary value consists in facilitating linkage between providers and users of the information, and to help disaster managers access relevant information more easily. It also facilitates the creation of new tools, such as an international coding system that would provide every disaster event with a unique reference number. A further example is AusDIN, the Australian Disaster Information Network – an Internet portal-based, multi-agency initiative.

Other useful tools are emerging for ground operations. One of these is vulnerability assessment, made possible thanks to advances in ICTs and the increasing availability of detailed data (*e.g.* from censuses). The purpose of vulnerability assessment is to describe the interaction between potential hazards, the community and the environment in order to develop programmes and strategies for managing the impact of disasters as effectively and efficiently as possible (and in the longer term, perhaps help reduce the vulnerabilities identified). Once a particular hazard has been identified, a matrix of relevant characteristics of the community and the environment can

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be constructed, including for example demographic, cultural, economic, infrastructural and environmental variables – the exercise could be called "intelligent community mapping". The demographic dimension might, for instance, profile the community in terms of age structure, mobility, health status (using such indicators as vaccination coverage rate, morbidity patterns, malnutrition rates), educational level (*e.g.* schooling and literacy rates), ethnicity, religion or other strongly bonded groupings. The infrastructure variables might include communication and transportation networks, community assets, etc., but also the organisational infrastructure of the community, such as provision of essential services, time needed to restore water supplies, and so on. Using this info, measures of the vulnerability and likely resilience of communities to disasters of various kinds can be constructed.

Since community life is more easily sustained when social networks are strong, having access to community profiles that shed light on such dimensions can clearly inform emergency management plans and responses in the event of disaster. But it can also help to develop civic responsibility and self-reliance, and build organisational capacities in the population. After all, a sense of place and belonging is an important aspect of community cohesion – and thus resilience – in the face of natural and man-made hazards.

The subsequent stage is to map out possible parameters for describing the effects of hazards on the community, and for highlighting its vulnerabilities. The WHO, in its 1998 Health Sector Emergency Preparedness Guide, sets out a useful illustration of such a set of parameters. It comprises a matrix of effects, measures and potential losses. The classification of effects ranges from deaths and injuries to disruption of infrastructure, damage to private property and environmental damage. Measures include the number of people affected, services disrupted, and scale and severity of likely damage. The losses are broken down into those tangible (*e.g.* loss of economically active individuals, replacement and repair costs, etc.) and intangible (social and psychological effects, cultural losses, decreased self-sufficiency, and so on).

In the case of disasters with international implications, well-functioning transnational systems for information gathering and sharing are a prerequisite for initiating speedy and effective emergency responses. The way has been led primarily by organisations and sectors with long traditions in safety assessment, inspection and information communication (*e.g.* UN Disaster Assessment Committees, UN OCHA, OECD, WHO, the nuclear industry and the chemicals industry). Recently, however, such schemes have begun to emerge in interesting new areas, such as the co-ordinated use of space facilities. (See Methodology Box 4 – Table 3 on the Charter to promote co-operation among space system operators, launched by ESA and CNES.)

With data gathering, information sharing and notification across borders of major newly emerging risks, relevant authorities and agencies face a set of peculiarly difficult factors associated with the very nature of these risks (low probability, high potential for harm, uncertainty of impact, knowledge gaps, etc.). Understandably, progress to date generally consists in building on measures undertaken in related fields. For example, with respect to new food-borne risks such as BSE, the European Union's new framework food law extends an existing rapid alert system for food to animal feed, and sets up an integrated Europe-wide information network to ensure that all countries quickly receive information on any risk to health posed by food or feed.

Similarly, moves are under way to strengthen international surveillance of infectious diseases by extending coverage to xenotrasplantation. The objectives would be to rapidly detect and report xenotransplantation-derived infectious disease events, promote information exchange, facilitate verification of xenogenic disease events, and support response co-ordination. It is not recommended that a brand new and totally autonomous surveillance network be created, but rather that synergies be achieved by using existing international surveillance systems, methodologies and tools (OECD – DSTI/STP/BIO(2001)11/FINAL). However, as Chapter 3 noted in relation to the effectiveness of global monitoring of influenza, any international surveillance network is only as good as the quality of its component parts; any weaknesses in national surveillance systems erode the quality of the international system.

3. Communication with the public and the media

The present situation

There are several important dimensions to communication prior to and in times of disaster. To begin with, there are procedures for informing of latent risks and warning the public of an impending threat, which may in itself have multiple purposes. It may simply serve to raise awareness of the public to the dangers, or encourage them to take certain precautions – such as not building one's house on a vulnerable flood plain or at the foot of an avalanche corridor, storing food and drinking water to meet essential needs for several days, obtaining vaccinations in case of epidemics, or guarding against virulent computer viruses. However, it may also serve to prepare people for evacuation in case of flooding, earthquakes, threats from radiation and so on. Once disaster has struck, there is a need to collect and disseminate information to the public about the extent of the damage, continuing threats and action to take, but also about the whereabouts of relations and friends directly involved. Finally, there remains the issue of handling and forging a useful relationship with the media. With the rapid diffusion of communication networks and the growing portability of reporting equipment – not to mention the worldwide appetite for news – the media are ever present at disaster scenes. This can be a boon to a stricken region, but it can also be a major hindrance to emergency operations.

The challenges

Three key challenges in this sphere of communication can be identified: first, that warnings and other information flows are based on accurate assumptions about human behaviour in time of disaster; second, that information is collected, communicated and disseminated effectively and efficiently; and third, that the appropriate balance is struck between ensuring information flows to and through the media, and guarding against disruptive intrusion by the media into the operations of the emergency services.

Assumptions about human behaviour

Misperceptions of human behaviour in times of crisis are widespread, and have come to be termed "disaster myths". These include the belief, for example, that once disaster has struck, people suffer severely from apathy and psychological dependency; that evacuation must not be called too soon for fear of causing panic flight; that looting becomes commonplace, and so on. Research conducted in recent years lends further support to the findings of earlier studies that populations' responses to disasters are overwhelmingly constructive – a heightened sense of social solidarity, pro-social behaviour, intensive community involvement, voluntary search for survivors. Erroneous perceptions of human behaviour as antisocial and irrational at such times are seriously detrimental to effective emergency management; they can hamper planning and response by leading to misallocation of resources and public misinformation.

Nonetheless, it would seem that certain conditions do in fact promote or discourage such constructive social behaviour. The myth mentioned above about the inherent tendency in threatened populations to flee in panic is one of the most enduring. This has in fact been found to be largely untrue. In most of the isolated cases observed in the past where panic flight did occur, a number of common circumstances prevailed – for example, the people concerned suffered a sense of complete social isolation, with little information about unfolding events and no one else to depend upon; and crisis management was seen to be largely ineffective. In other words, the challenge in generating and maintaining responsible behaviour among populations in times of disaster is to ensure timely and credible information, reduce uncertainties to the extent possible, and engender citizens' trust and confidence not only in the emergency management services and relevant authorities, but also in their own capacities to cope and contribute.

In addition, new sources of systemic risk are emerging which may or may not result in behavioural responses similar to those triggered by more traditional disasters. Some analysts maintain that disasters provoked by certain technological agents (nuclear accidents, chemical accidents, major oil spills) engender social and behavioural patterns that are distinct from those engendered by certain natural disasters (flooding, hurricanes, etc.), but such assertion is the subject of much debate – see Tierney, Lindell and Perry, 2001, for an extensive discussion on this distinction).

If this is indeed the case, it would seem justified to reflect on whether new systemic hazards such as bioterrorism or new infectious diseases might in turn be associated with distinct generic behaviours. The recent anthrax attacks in the United States fortunately affected only a few people directly, but they highlighted the kind of information and communication problems that a much larger-scale attack would no doubt magnify many times. For instance, unless the release of the agent were announced or discovered fortuitously at an early stage, there would be no discrete event to signal that such an attack was under way, no easy way of identifying the site of the release, or of determining whether the release was deliberate, accidental or a natural occurrence. Informing the public and emergency services appropriately under such constraints of uncertainty clearly becomes a very complex task indeed, not least because the behaviour of citizens in such circumstances is difficult to predict. It also opens up debate about the appropriate degree of civic involvement in the state of preparedness, *e.g.* how much effort to expend on strengthening individual or local capacities for early warning, communication, response and so on.

Communication with the public

Timely warning of an impending disaster is of course essential to saving lives and property. It enables mitigation measures to be put in place, allowing defences against the threat to be established or preventive vaccinations to be carried out or evacuation of the population to be set in train, and so on. A key to the success of such measures is the appropriateness of the communication tool and the quality of the message to the various agencies and decision makers involved in the emergency operations as well as to the broader public. Similarly, prior to, during and in the aftermath of disaster (conventional or otherwise), handling enquiries from the public can be a daunting task. Often the sheer volume of requests for information can place a heavy burden on emergency management's resources and prove highly disruptive by jamming telephone circuits, jeopardising essential public safety activities.

The media

Finally, most disasters are a media event. Effective interaction with the media can therefore be of critical importance in reducing losses. As noted above, in those types of disasters where warning is possible before the event, accurate, timely and consistent information conveyed by the media can be decisive in preventing death and injury. The media can be used to convey instructions to the public, they may stimulate donations, reinforce efforts to gain broad public support for mitigating actions, engender confidence in community leadership, greatly reduce the number of enquiries from the public, and provide useful coverage that may facilitate future funding campaigns (although whether funding should rely substantially on voluntary contributions is itself an open question).

At the same time, however, many an emergency manager experiences considerable frustration when having to divert much-needed time and resources to address the demands of the media, while at the same time trying to mount a multi-organisational disaster response under conditions of extreme urgency and uncertainty. The risk is always present that the media may get in the way of operations, distort the facts of the drama, or help to perpetuate disaster myths. This argues for careful media relationship planning before the event. The absence of such planning can have hugely disruptive consequences. When the nuclear reactor accident at Three Mile Island (in the US state of Pennsylvania) became known, for example, three commercial TV networks established operations in the area. Each brought 75-100 reporters, editors, managers and technicians. These were joined by camera and reporter teams from individual TV stations in nearby towns and cities. Unfortunately, no planning time had been devoted to establishing procedures or to setting up mechanisms to handle the massive demand for information on what was a very complex incident (Holton, 1985).

The impact on the decision-making processes and information flows during the incident proved critical. The Commonwealth of Pennsylvania did in fact have an emergency response plan already in place to deal with just such a nuclear reactor accident. The pivotal role was to be played by the Pennsylvania Emergency Management Agency. As the crisis unfolded, however, the plan – which had the State Emergency Management Organisation handling many operational aspects, leaving only major decisions to the governor – had to be abandoned. All decisions and communication responsibilities were passed to the state governor's office. In the words of Wenger (1985):

> The entire system had evolved into that of "emergency management by press conference". Under the stress of monumental media attention and demands, state and federal authorities centralised all decisions and

> information distribution within the Governor's office. This alteration effectively isolated the state's emergency management system not only from active involvement in decision making, but also from the receipt of information. Local and state emergency management officials, who had planned to be centrally involved in the response, often found it necessary to listen to radio and television press conferences in order to find out what was happening.

It has been estimated that if a nuclear reactor incident on a par with Three Mile Island were to occur, the numbers of media personnel responding in the first 24 hours would be three times as great (Auf der Heide, 2000).

Emerging responses

An important key to improved responsiveness to disaster warnings among affected populations is the extent to which a culture of risk already prevails. The ultimate (albeit unattainable) objective of disaster preparedness is to generate in a population previously unaffected by major disasters the same level of knowledge, reflexes and social and organisational behaviour as is found in communities that have suffered from a major disaster at first hand. (It has to be said that even communities that have previously suffered a disaster do not always learn from the experience.) Part of the solution lies in the provision of training programmes for disaster management, part in ensuring widespread access to preparedness information.

Some countries have begun to devote serious effort to the first solution. The US Government and the Australian Federal and State governments, for instance, have stepped up education and training substantially. In the United States, the Federal Emergency Management Training Center and the Emergency Management Australia Institute provide regular training sessions for emergency managers, and the Department of Defense has initiated new training activities to prepare the population for possible chemical and biological terrorist attacks. Moreover, some 30 US colleges and universities now offer courses, certification programmes and even advanced degrees in emergency management and, in some cases, courses in the sociology of disasters.

On the second issue of information accessibility, progress is being made on numerous fronts. A survey by Fischer (1998) of government agencies and disaster organisations in various countries, including international organisations and NGOs, revealed that their websites not only contained standard information on staff, research programmes, publications, etc. but also detailed and specific information on preparedness and mitigation as well as on-line, "hands-on" assistance such as how to prepare one's home for a hurricane or flood.

More fundamentally however, successful disaster preparedness and mitigation turns on the responsiveness of the public as a whole. There are interesting illustrations of this from across the OECD area. Sweden for example has ensured for many years that knowledge about and skills for addressing major disasters form an integral part of education in schools. Quebec, Canada has introduced legislation that constitutes a broad-based, systemic approach to disaster preparedness and planning, encouraging a culture of civil security at all levels, from the individual citizen through to the various levels of municipal and regional government. Japan, on the other hand, has created a regular Disaster Prevention Day (Methodology Box 1).

But how are populations likely to react to a new class of disasters, those related to emerging systemic risks such as bioterrorism or chemical attacks? To what extent can assumptions be made about human behaviour in such events based on behaviour in "conventional" disaster situations? What can be done to bring about any necessary adjustments? Pointers to meeting such challenges in the future are provided in the growing literature on self-organisation. Work for example conducted by Comfort (1999) and others on seismic disasters across the world suggest that policy makers and planners who focus on procedural rules and externally imposed requirements are less likely to achieve the desired awareness, preparedness and co-ordination than those utilising a common information infrastructure and a shared knowledge base prior to the destructive event (elements encouraging learning processes and voluntary co-ordination). It has to be noted that self-organisation is not a substitute for but a particular approach to planning, preparedness and emergency action co-ordination, and that trust and confidence in those responsible for addressing the crisis remains a crucial factor. A key issue for the future will be how to find the right balance between the two.

The appropriateness of the communication tools used in a disaster situation and the clarity of the messages issued are key to effective emergency management. Depending on the prevalent risk culture of the population concerned and the complexity of the situation at hand, different approaches may achieve similarly satisfactory outcomes. Two examples from different parts of the world on two kinds of natural catastrophe serve to illustrate the point. The January 2002 bush fires in Australia, while costly in terms of environmental damage and loss of property, had a remarkably low casualty rate. Local populations prepared themselves by undertaking actions to reduce fuel loads, and then were warned through a simple but highly effective method of the impending threat and necessity to evacuate: circulars placed in people's letterboxes (Hagan, 2002). At the other extreme in terms of complexity of operations and communications is the co-ordination system in place when the River Loire in France threatens to cause major flooding (Case Study 1).

Methodology Box 1. **Emergency drill in Japan**

Since 1961, Japan has had a Disaster Countermeasures Basic Law which provides for the co-ordination of various disaster-related measures such as preparedness, emergency response, recovery, etc. In 1995, the Basic Plan for Disaster Prevention, which is based on the Disaster Countermeasures Basic Law, was revised to stipulate that emergency drills should be conducted as part of a national effort to enhance preparedness and enable Japan to better resist and recover from seismic shocks. The Plan also states that emergency drills for large-scale disasters should be conducted jointly between government organisations and local public bodies and that the co-operative relationships between these entities should be strengthened; and it further stresses the importance of the community's own efforts in ameliorating the effects of disasters.

The first comprehensive drill for disaster prevention was held in 1971, albeit involving only a small number of organisations. Since 1982, an annual "Disaster Prevention Day" (1 September) has been held during a "Disaster Prevention Week" (30 August to 5 September), involving exhibitions, emergency drills and other events, with the aim of raising citizens' awareness and enabling the dissemination of disaster prevention literature. This opportunity is used to enhance the disaster prevention activities undertaken by relevant organisations, companies and other private organisations and residents of local communities. A comprehensive emergency drill is now conducted by the government in designated areas on every Disaster Prevention Day. Since the Great Hanshin-Awaji Earthquake in 1995, the drill has been modified to incorporate lessons learned from an event and the improved government system instituted in its wake. In this drill, the prime minister convenes a conference of the relevant ministers and declares a state of emergency. This is followed by a meeting of the Headquarters for Emergency Disaster Control with the participation of all cabinet members.

The 2001 comprehensive disaster prevention drill involved two major regions, Tokai and Southern Kanto, and involved 33 administrative organisations, 20 public agencies and 13 prefectures. The Tokai earthquake drill involved some 1.5 million people participating from the Tokyo metropolitan area and six prefectures. The Southern Kanto Drill was held at the Prime Minister's residence with the participation of all cabinet members. A teleconference was held between the Government Headquarters for Emergency Disaster Control, the National Police Agency, the Defence Agency, the Fire Defence Agency, and the Ministry of Land, Infrastructure and Transport. An exercise was conducted to test the information transmission system developed by the Maritime Safety Agency for sending and receiving pictures from areas affected by the earthquake. A total of 467 000 people participated, representing seven prefectures and cities.

Source: NIRA.

Actually organising information collection and dissemination to the public following a disaster is a complex task. It would appear that the most effective method is to combine centralised solutions with devolved ones. Responding to enquiries about family and friends often entails information from a wide range of organisations – law enforcement agencies, the coroner, public shelters, local hospitals, etc. – and that necessitates establishing a central, multi-organisational public information office. These in turn can be organised into a regional interconnected system that channels as many enquiries as possible away from the scene of the emergency activity and thereby reduces potential disruption.

Finally, planning in the area of media impact is of paramount importance, as noted above. It seems to be most effective when the media are already involved in the disaster planning process – that is to say, arrangements are planned with the media rather than for them. Involvement on their part can be restricted to merely being kept informed of plans or consulting in the design of the plans. Depending on circumstances, it might also entail delegating responsibility to the media by providing them with an active role in emergency operations.

The handling of the ice storm in Quebec, Canada in 1998 offers some useful indications of how new approaches are being applied to relations with a responsible media in times of crisis. Three successive waves of heavy snowfall in five days paralysed electricity distribution (there was a 75mm-thick coating of ice on cables), transport networks, drinking water supplies and many other vital sectors. Evacuation of Montreal was seriously considered. The usual command-and-control approach to crisis situations was abandoned in favour of a strategy of trust building and collaboration with the public, politicians and the media. A major media centre was established at the headquarters of Hydro-Quebec and regular briefings were organised with journalists. Rules of the game were established. For example, no interviews would be given on speculation about the causes of the crisis, only on the facts – but technical briefings were held for those journalists interested in detailed information. The specialists working on emergency operations were available for such interviews but at no other time, thus significantly reducing disruption to their work. The president of Hydro-Quebec appeared at the daily press conferences, accompanied by the premier of Quebec. Their statements focused on the objectives to be achieved for the day. Straightforward, non-technical language was used, and their message was aimed at generating solidarity, trust and a sense of achievement (Lagadec, 1999; Commission scientifique et technique chargée d'analyser les événements relatifs à la tempête de verglas survenue du 5 au 9 janvier 1998, 1999).

4. Efficiency and effectiveness of emergency services

The present situation

Although it is not possible to plan for every contingency, experience with past disasters suggests that some problems occur with such regularity as to be amenable to planning. For example, almost every major disaster requires procedures for the centralised gathering and sharing of information about the overall situation as it unfolds, available (and prospective) resources, and how and with what effect the latter are being applied.

Agreed procedures are needed for overall co-ordination (deciding what organisations are going to carry out what tasks and how they are going to interact) and the logistics for, *e.g.*, material supplies, transport, food, shelter, and communication networks to support the disaster response. Other examples include procedures for integrating and managing volunteers; warning threatened communities; handling evacuations; carrying out triage; co-ordinating search and rescue; keeping unauthorised people out of the affected area; distributing casualties rationally among the available hospitals; decontaminating equipment and casualties exposed to hazardous materials; dealing with the press; and responding to seemingly endless enquiries from anxious relatives of those thought to be potential disaster victims. This idea of focusing on generic tasks faced in most emergency situations has been built into the emergency management processes of many countries. Nonetheless, despite the fact that these predictable aspects of disaster response can be anticipated and planned in advance, each disaster will to some extent be unique. This may especially be the case with new kinds of emergencies in the years to come.

The challenges

Broadly speaking, the challenges facing managers in today's context of disaster response are threefold: how to plan adequately prior to the event; how to co-ordinate operations in a disaster environment when both the impact of the disaster and the means with which to address it are increasingly complex; and how to respond to emergencies triggered by less familiar systemic risks.

Planning

In disaster planning much of the emphasis is on quickly mobilising – and, if necessary, equally rapidly supplementing – resources to mitigate threats to life, property and the environment. Speed is usually of the essence since the sooner help is at hand the more effective mitigation will be, including prevention of further adverse effects. Indeed, it is usually those who arrive on

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the scene first (often before professional assistance) who can help most in terms of saving lives and preventing further injury. At the same time, uncontrolled mobilisation and over-response can also cause problems, particularly in co-ordination and communication. Well-rehearsed and widely understood and accepted procedures for disaster planning are clearly important, including providing non-professional first-responders with basic skills.

When disaster strikes, people naturally want to volunteer the services of their organisations and/or to help personally. But while disaster-stricken communities may clearly need resources, it can be very difficult for outsiders to get accurate information on what the actual needs are (including whether they have already been or are being met). Too many volunteers acting independently risk getting in each other's way.

Part of the typical response to a disaster, then, is a set of actions initiated by a multitude of independent organisations and agencies in the public sector (local, regional, national governments, fire and police services, etc.), the private sector (utilities, private hospitals, doctors, etc.) and the voluntary sector (NGOs). If these agencies have planned independently of one another, this tends to result in discrete responses and a failure to fit them into an overall picture. The difficulty for comprehensive, integrated preparation for disaster is how to plan for the largely unplannable:

> Organisations change structure, with various positions being filled by different persons. Multiple organisations are faced with overlapping areas of responsibility. Many activities are taken on by unsolicited volunteers. New tasks, sometimes requiring unusual resources, present themselves for which no one has clear-cut responsibility. New organisations even come into being. Multiple organisations are faced with the need to co-ordinate activities with each other on a moment-by-moment basis, without familiar procedures for carrying this out. Furthermore, all this may take place under conditions of extreme urgency, which virtually precludes the time required to develop the necessary co-ordination. (Auf der Heide, 1989).

On top of this comes the necessity to control escalating operations as initial action at the local level is gradually complemented by resources drawn in from the regional, state or national level. It then becomes essential to ensure compatibility of plans at the various levels so that each dovetails into the next highest level of planning within an overall framework (Abrahams, 2001).

An important element of the planning is the technological dimension. It needs to be ensured, for example, that once emergency operations swing into action, there are no unpleasant surprises with respect to the reliability of communications. Past experience in this regard has revealed a diverse range of problems, beginning with inadequate provision of communication channels in an emergency situation. The response of emergency personnel to the Sarin attack on the Tokyo metro in 1995, for instance, was considerably handicapped by the lack of capacity to cope with the flood of calls precipitated by the incident. Importantly, overload prevented the on-site and mobile medical teams from communicating properly with their hospital-based supervisors and obtaining vital information about what treatment to administer and which hospitals could take casualties (WHO, 2001). Other problems include lack of interoperability of cellular phone systems used by different organisations, insufficient redundancy in the form of back-up communications, and cellular systems in general use that are sometimes more advanced than emergency agencies' own systems (OECD, 2000c). Similar problems have been experienced with lack of radio frequency compatibility.

Co-ordination and communication

The importance of good communication in emergency management lies in its ability to get people to work together on a common task or to achieve a common goal. It is the process by which each person understands how his or her individual efforts intermesh with those of others. This is easier to achieve within an organisation than between different organisations (*e.g.* within a fire or police department rather than between them). Frequently, what are perceived as communications problems are actually co-ordination problems in disguise (Brunacini, 1985). Thus, while good co-ordination cannot be achieved without good communication, the latter will not guarantee the former.

Co-ordination of task accomplishment, situation analysis and resource management between multiple organisations requires efficient and effective inter-agency communication. This requirement transcends obvious aspects like appropriate communications hardware (*e.g.* radios with compatible frequencies) to include, *e.g.,* agreed communications protocols and procedures (*i.e.* adherence to common standards).

Persons working for one organisation often appear reluctant to contact people working for others, even when the means of communications are to hand. This basically seems to boil down to issues of familiarity and trust. Not surprisingly, when responding agencies have interacted and co-ordinated with each other beforehand, they have had fewer problems doing so in crises (Kilijanek, 1981). Trust can be bolstered by clarifying at the outset of communication what an agency's role is in the overall response to a disaster, what the particular person's role is, and his or her ability to perform the role competently. Arguably, however, the implicit level of trust needed for high-level team performance in life-threatening situations is only likely to be earned by virtue of extended pre-incident contact, where that competence can be demonstrated.

Needless to say, inter-agency co-operation is adversely affected by pre-existing personal, political and jurisdictional antagonism (*e.g.* both the police and the firefighters may presume that they are in overall charge of the situation, or perhaps each thinks the task falls to the other agency). If such disputes continue unresolved on a day-to-day basis (*e.g.* in routine emergency situations) they are unlikely to be magically resolved in a disaster, when teamwork is most needed. The ultimate objective is to achieve among the relevant agencies a shared culture that enables each party to judge what the other parties are likely to do, permitting implicit co-ordination even when explicit co-ordination breaks down.

This raises a key issue in terms of the structure, organisation and implementation of the co-ordination exercise itself. In many areas, emergency response and public safety management is patterned on the military model, reflecting a widely held belief that such operations are carried out most effectively under rigid control exercised by one commanding entity. It has to be said that in the routine operations conducted within many of these organisations, such a highly centralised authority may indeed be appropriate. But for major disasters on a regional, national or international scale, it is clearly impractical. In most OECD countries there is rarely a single organisation that can legitimately control the operations of all public and private organisations in the event of a peacetime disaster. Co-ordination among the various independent entities responding therefore needs to be based on negotiation, co-operation and joint decision making, even though ultimately consistency and coherence of decision making must be ensured. This highlights the difficulty of striking a workable balance between centralisation and control on the one hand, and decentralisation and joint decision making on the other.

When planning for transnational disasters, it is important to consider whether or not organisations will depend on their foreign counterparts for information, direction and resources (Wachtendorf, 2000). Facilitating cross-border interaction during routine emergencies can improve interaction during disasters. Proximity, availability, expertise, and the existence of established relationships can sometimes make assistance from a neighbouring country faster and more efficient than local help. In fact, organisations across the border may have a vested interest in the well-being of their foreign counterparts. In transnational disasters, issues within an organisation's own jurisdiction take priority, but these same organisations are often willing to assist agencies in the other country as soon as they are able to do so.

Again, co-ordination is the key. The organisation of aid and rescue operations is often complicated by the intense mobilisation of voluntary organisations and donors with different objectives, approaches and cultures. Lack of infrastructure, inappropriate aid contributions and unco-operative behaviour on the part of many of the actors and their organisations may also hamper operations and lead to significant over- or under-response to an emergency. The International Federation of Red Cross and Red Crescent Societies (2000), for example, is frequently critical of the co-ordination vacuum affecting many international humanitarian relief efforts; Albania and Kosovo are recent examples. Similarly, WHO has expressed concern on many occasions about the deficiencies in the cross-national co-ordination of aid agencies' public health responses to major crises. In successive disasters, vast quantities of often inappropriate medicines have flooded in from companies and donors in a completely *ad hoc* fashion, and strict guidelines developed by WHO with leading medical groups are often not enforced. Against this background, the need for an international co-ordination framework takes on added urgency.

International interdependencies argue for an international response if mitigation is to be successful. This adds a further layer of complexity to national efforts at emergency management, and thus adds to an already daunting task. Arguably, however, the same principles derived from the study of past disasters continue to apply: how best to put in place effective and efficient processes and plans, co-ordination and communication mechanisms, and swiftly deploy other crucial support systems – only now on an international rather than national or local scale.

New, emerging systemic risks

To what extent might different co-ordination criteria apply to emergencies caused by new, emerging systemic risks? At first sight, this might seem to be primarily a question of scale of response. Certainly from a planning perspective there are a number of aspects that give rise to concern if only because they highlight the sheer size of the logistical effort required. However, on closer scrutiny, other challenges soon become apparent.

As was noted earlier in this chapter, patterns of individual and organisational behaviour triggered by natural disasters can differ from reactions to technology-related ones. From the co-ordination and communication points of view, a key difference frequently observed in studies of recent chemical accidents and oil spills (*e.g.* the 1989 Exxon incident) is that, unlike many natural disasters, these tend to erode inter-organisational and community consensus rather than increase it. This lack of consensus frequently clouds questions of authority and responsibility; it becomes uncertain which organisations should participate in the response; and ambiguities surface about the course of action to be taken (Tierney, Lindell, Perry, 2001). With new emerging systemic risks, expectations about whether co-ordination of disaster response will be consensus- or conflict-driven remain largely untested.

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Emerging systemic risks may also pose problems of great logistical complexity. In case of a massive terrorist attack with a bio-agent, for example, millions of people could be affected, causing a huge surge of patients in a country's hospitals. Mass medical treatment, both preventive and curative, might have to be administered under extremely difficult exposure conditions, perhaps complicated by additional infection-control requirements (such as quarantine). To the extent that the health system is already operating at or close to full capacity (this applies to many OECD countries where reforms and efficiency drives have greatly reduced surplus capacity), the strains on medical health infrastructures and services could easily lead to severe disruption. (In the winter of 2000 it only took a relatively severe influenza epidemic to bring many UK hospitals to the brink of their operational capacity.) The response therefore would need to involve not just a raising of the scale of planning but also the design and implementation of innovative strategies to ensure that resources were effectively co-ordinated and treatments successfully delivered. If the attack were to involve a smallpox agent, for instance, vaccination would need to take place just days after exposure in order to be effective. A large-scale attack in several places simultaneously would clearly present huge vaccine delivery problems.

Equally important is the issue of adequate stockpiles of vital drugs and medical equipment. Stockpiles need to be reviewed, expanded and improved, taking into account the latest intelligence on credible terrorist threats. Where there are capacity problems or issues of large-scale timely delivery of drugs to resolve, new arrangements might well be required. For instance, stockpile investments might also include contractual agreements between the authorities and pharmaceutical manufacturers to ensure additional production capacity for medicines and vaccines in times of crisis (Hamburg, 2001 and see Case Study 3 for parallels with infectious diseases).

Finally, in preparation for incidents that would affect several countries, planning would need to encompass co-ordination of emergency responses across borders. Given the ease and speed with which virulent bio-agents might travel and spread across vast areas, a good case can be made for individual countries to ensure that their drug and vaccine stockpiles can also be used for incidents in other countries.

Emerging responses

Studies on the subject offer cogent evidence that some planning models and approaches are better than others. Recent years do seem to have witnessed a shift away from military-type command-and-control methods towards models that aim to enhance the problem-solving capabilities of emergency services and communities alike. In response to the growing need for joint, inter-organisational direction and decision making, these new approaches tend in practice to assign responsibility to the heads of individual agencies; it is up to them to determine their needs and take initiatives to develop co-ordination arrangements with other agencies. The overall co-ordinator may be selected by the agency directors involved, and act on their behalf. This results in closer matching of planning with local needs, and broader acceptance on the part of those actors embraced by the plan.

Australia's Emergency Management System, for example, is based on a framework which, in addition to containing elements of identification, alert, assessment and prevention of risks, also comprises:

- A programme for mitigating emergencies and disasters.
- Identification of those responsible for all aspects of comprehensive emergency management and planning.
- Allocation of well-accepted support roles and responsibilities.
- Co-operation between emergency services and others, and clarification of their roles in emergency management.
- A co-ordinated approach to the use of all resources.
- Arrangements to enable communities to recover from disasters.

In recent years this system has been applied to a range of major incidents and events, including the emergency planning for Y2K and the Sydney Olympic Games (Abrahams, 2001).

At international level, numerous initiatives point the way to much improved frameworks for disaster planning. In the category of the more "conventional" hazards, the OECD in 1992 published Guiding Principles for Chemical Accident Prevention, Preparedness and Response, a document intended to assist public authorities, industry, labour and other stakeholders in establishing policies and programmes related, *inter alia,* to accidents involving hazardous substances. These guidelines were revised and updated; the second edition was published in 2002.

Similarly in the health sector, WHO in 1998 produced its Health Sector Emergency Preparedness Guide to fill what was considered a conspicuous gap in health sector guidelines on preparedness for national and local emergency co-ordinators as well as regional focal points. It contains essential organisational and procedural advice on emergency planning, ranging from roles, responsibilities and management structures to information and resource management. More recently this has been supplemented by WHO guidelines on public health response to biological and chemical weapons (WHO, 2001).

A recent addition to international frameworks for emergency preparedness and response in the nuclear field is the Joint Radiation Emergency Management Plan of the International Organisations (IAEA, 2000).

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It describes the basis for systematic, integrated, co-ordinated, and effective preparedness and response in the event of a nuclear accident or radiological emergency involving facilities or practices that may result in a threat to people's health, property or the environment. It sets out for such organisations as the IAEA, WHO, NEA, WMO and FAO the responsibilities, guiding principles, response structures, co-ordination arrangements, etc. in case of radiation emergencies.

As in the case of planning, important developments can be observed in disaster response co-ordination approaches, some of which provide an indication of how organisational networks are addressing the difficult trade-offs between centralisation versus decentralisation, unified leadership versus participatory involvement, and coherence of structure versus autonomous action. What emerged from earlier investigations into the functioning of search and rescue operations in the United States, for example (Drabek, 1983, 1985; Drabek *et alia*, 1982), is that certain generic conditions favour effective co-ordination of the emergency response. These include:

- Consensus among the organisations involved, achieved when each entity understands the purpose of the network and its own role as well as that of the other entities.
- The presence of an identified leader possessing legitimate authority and expertise, operating through a central co-ordinating mechanism (*e.g.* an emergency operations centre).
- Frequent contact and interaction among the organisations prior to the disaster, especially through periodically arranged joint exercises, since establishing consensus and authority structures during the onset of a major disaster is extremely difficult.

Such generic aspects are reflected in the concept of the Incident Command System (ICS), increasingly used in recent years. Irwin (2000) describes ICS as:

> "… a management system, developed around specific design criteria and modern management concepts. There are five functions in the System, designed with a clarity that improves effectiveness, accountability and communications. ICS uses an incident action planning process that is systematic and comprehensive; multiple agencies and emergency response disciplines can be integrated into a common organisation using the process. The unified command concept used in ICS provides the most effective means of co-ordinating and directing multiple disciplines on major civilian emergencies."

The key advantage of the ICS is that it functions on the basis of commonality. Instead of several independent command posts, there is only one; the operation can be directed from one single location; only one set of plans is needed instead of several; and only one collective, integrated procedure for logistics and communications is required. Moreover, its generic strength means that it can be applied to improving emergency response operations of all types and complexities.

Indeed, the complexities of handling international-scale disasters can be several orders of magnitude greater than those associated with domestic emergencies. This is especially the case where incompatibilities of rules, laws and regulations among countries significantly hamper disaster relief and humanitarian aid operations. In this regard, some interesting initiatives are under way. For example, the United Nations General Assembly adopted in 2002 a resolution developed in the International Search and Rescue Advisory Group (INSARAG) which will facilitate the sharing of urban search and rescue resources and expertise and the provision of assistance. And the International Federation of Red Cross and Red Crescent Societies is developing an assessment of the current state of international disaster response law, as described in Methodology Box 2.

For some years now perceptions that the risk of bioterrorism is growing has stimulated planning and co-ordination responses across a wide range of administrative levels, sectors and services. The Department of Health of England and Wales, for example, in 2000 published fairly comprehensive planning guidance to health authorities to ensure that they set in motion plans for an effective response to the deliberate release of biological and chemical agents. Since the events of 11 September 2001, planning has been strengthened throughout government (Chief Medical Officer, Department of Health, 2002), by means of :

- Further planning guidance provided through regional directors of public health to the local health service and public health services.
- Clinical guidance to all doctors through the Public Health Laboratory Service on anthrax, smallpox, botulinum, tularaemia and a wide range of chemical hazards.
- Guidance on securing drugs and other supplies and the logistics for delivering them to where they might be needed in an emergency.
- A joint collaboration agreement signed with the United States, and joint work with European countries and Canada.

The report does note, however, that further action in this field is essential, notably the development of contingency and emergency response plans, ensuring co-ordination of plans and appropriate stores of vaccines, and forward thinking and innovation in identifying and protecting against vulnerability to the release of biological agents.

Illustration Box 2. **The need for legally enforceable international disaster standards**

There is no doubt that international disaster response is more effective and more efficiently co-ordinated with internationally agreed standards in place. These must include clearly identified described mechanisms that are suited to the needs of disaster-stricken countries and their governments, as well as to donors, intergovernmental humanitarian agencies and NGOs. The agencies, including the International Red Cross and Red Crescent Movement,* have done much to enhance and develop technical co-ordination, standards and codes of conduct in this area.

However, in the view of the International Federation, the pertinent legal framework needs to be significantly improved if it is to create genuinely favourable conditions for effective disaster response. Many national and international (bilateral, multilateral and customary) legal instruments exist, ranging from loose recommendations or guidelines to hard treaty law invoking the responsibilities of states. This wide definition of international disaster response law covers humanitarian response to natural and technological disasters, including in the areas of disaster prevention (or risk reduction) and preparedness. These instruments – at times they could be accurately called "isolated clauses" – are scattered throughout other legal domains such as environmental law, air and space law, development law and the like. As a result they are sometimes too narrowly known to be of significant benefit at the time of a disaster.

Similarly, it is clear that where international law or rules have been established, they are often not well known outside the capitals of the countries themselves. This can lead to confusion at the local level when a disaster also interrupts communication and lines of authority between the capital and the disaster site.

With this in mind, and taking account of the situation described in the World Disasters Report, the International Federation's Disaster Relief Commission recommended action to support what has become known as the International Disaster Relief Law initiative. This is aimed at drawing together the scattered threads of hard and soft law currently in force to enable states, national societies, humanitarian agencies and others with an interest in the subject to determine the need for action in a variety of related fields.

A possible three-step action plan has been designed:

- The compilation and publication of all existing and relevant international law, rules and other instruments.
- The collection of field experience and an evaluation as to where existing rules do or do not respond effectively to the requirements of humanitarian actors in the field.

Illustration Box 2. **The need for legally enforceable international disaster standards** *(cont.)*

- The identification of ways and means to improve the law, or to address recognised difficulties in non-legal ways.

This action plan has in the meantime been transformed by the International Federation into a concrete work plan after further consultations with interested national societies and the International Committee of the Red Cross (ICRC).

* The International Red Cross and Red Crescent Movement consists of the International Federation, the National Societies and the International Committee of the Red Cross.

Source: The International Federation of Red Cross and Red Crescent Societies.

5. Disaster containment

The present situation

In addition to what can already be done prior to the disaster, the speed of response and degree to which the action taken is effective and efficient immediately after a disaster are crucial to limiting its consequences. Prompt action to save life, limb and property and curtail economic and environmental damage can greatly lessen the magnitude of losses by preventing the propagation of adverse consequences via second-round or indirect effects. Equally, however, the system delivering the emergency services needs to be sufficiently resilient under shock so as to be able to contribute to damage limitation.

Response decisions to disasters, however, often also involve difficult policy choices. Depending on the information available and the course of action chosen, some population groups may obtain relief before others, some sectors may have to be helped earlier and more extensively than others, and the impacts of the measures implemented on various parts of the community may not only differ significantly but also come in unexpected guises. This latter argument holds equally when international implications are at stake. Again, the more holistic the view of the decision makers and the more timely and accurate the information available, the greater the likelihood that sound, well-reasoned decisions will be taken and the element of surprise reduced.

The challenges

As noted previously, disasters tend to be characterised by significant levels of uncertainty. Often the character and extent of damage and secondary

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threats (*e.g.* leaking chemicals, downed power lines, weakened dams) are not immediately clear, and necessary countermeasures are therefore not pursued. Initial actions may be taken based on vague and inaccurate information. Disasters tend to be fluid in nature, giving rise to needs that can change from moment to moment.

Speed of response

From the perspective of those responding to a disaster, limiting damage will hinge on how soon the fact of a disaster is known, whether responders (particularly first-responders) know what has to be done, how long it takes to marshal the necessary resources, and when others who may be affected (either directly or indirectly) are apprised of the situation.

Good intelligence and communication systems can help with prompt alerts of impending or actual disaster (weather forecasts and seismic monitoring are examples). However, systemic risks (exacerbated by the sheer complexity of many vital systems and growing interdependencies that affect both the hazard itself and the potential response) often militate against anyone other than professional responders being in much of a position to know what needs to be done once disaster strikes (save for the obvious, immediate actions those first on the scene can take to save lives and property).

Speed of response is closely linked with the capacity for identifying prior to or in the aftermath of the disaster those groups of people, places, networks or natural phenomena that constitute the greatest danger in terms of their potential to propagate negative effects. In matters of infectious diseases, these are the so-called "site amplifiers". Garrett, for example, identifies hospitals, the use of syringes, blood banks, and sexual behaviour as examples (1995).

Resilience of emergency systems

In order to have the greatest possible impact in terms of saving lives and property, a variety of emergency response systems – whose components need to work flawlessly, both sequentially and in parallel – may need to be deployed promptly and simultaneously. It is at this juncture that the resilience of these systems themselves comes into play. Even the most speedy aid and rescue operation can founder, and damage limitation be seriously hampered, if it proves impossible to preserve the continuity of vital systems and services.

Telecommunications are a case in point. The August 1999 earthquake in Turkey cost more than 15 000 lives and material damage of some USD 16 billion, including extensive damage to the telecom networks. On a normal day, the network carried some 3 million calls to the regions of Izmit, Adapazari and Yalova, of which 99% were successfully connected. In the aftermath of the earthquake, levels of congestion were crippling. More than 50 million calls were attempted daily, of which only 11% were successful. Emergency services operations were seriously affected not only because the seismic resilience of telecom cables proved insufficient and the cellular antenna sites within the disaster area stopped functioning, but also because there was insufficient prioritisation of calls going out from the disaster region (OECD, 2000b). The problems of operational reliability and congestion of cellular networks are of course more general ones. Cellular carriers in many countries have never been regulated for emergency telecommunications provisioning, and in some countries new competitors do not have to meet the same standards of quality as incumbent operators. More broadly, many countries do not even have an emergency telecommunications policy framework.

On the medical front, what seems to matter most in predicting how well communities are able to withstand the adverse health effects of a disaster is the strength of the public health system in place prior to its occurrence. There seems to be a widespread belief that the primary role of public health in disasters is to control potential outbreaks of communicable disease after the event. While it is true that the potential for such outbreaks and even epidemics of infection exists after any national disaster, the actual occurrence of such outbreaks has been rare (Noji, 1997). (In order for a risk of epidemic to exist, the disease needs to be present in the population beforehand.) What is important is to ensure the maintenance and quick restoration of sanitary services and drinkable water to affected communities, as well as routine surveillance of the population's health status (Kimberley, Shoaf and Rottman, 2000).

Apart from disaster-related structural damage, a major cause of incapacitation of key health infrastructure such as hospitals is disruption to water, power and telecommunication services – without these the health care system cannot function. Water damage from initial flooding by activated sprinkler systems can be a particular problem, often causing loss of medical supplies, short-circuiting vital equipment (*e.g.* laboratory testing machinery and computers) and medical records. Although significant components of the health care system such as hospitals often maintain backup systems (*e.g.* power and water), such systems can also fall prey to a disaster and in any event are only designed to tide things over for a limited period. Clinics, doctor's rooms and pharmacies rarely incorporate such redundancies, on cost grounds.

In addition to the direct impacts that disasters have on a population's health, there are indirect effects. Over and above the emotional or psychological toll taken by disasters, these effects result partly from the loss of routine health care as a result of both damage to the health care system and the possible overloading of the system with trauma cases. For example, there are primary health care needs which, if not met, will adversely affect the population. Immunisation, prenatal care, management of chronic medical conditions such as diabetes and cardiovascular disease are examples of services that need to be maintained and provided to affected communities.

Depending on the seriousness and scale of a disaster, bulk shipment of needed supplies of food, drinkable water and shelter can overwhelm even the capacity of developed countries to cope with disaster – in which case mitigation efforts will need to involve international co-operation and co-ordination.

Achieving the holistic perspective

On the broader issue of policy trade-offs in emergency situations, the complexity and inter-connectedness of modern economies and societies make it increasingly imperative to assess possible countermeasures from a point of view that encompasses as wide a picture as possible of the likely repercussions of those measures.

For example, preventive action taken well ahead of a major incident may have the unanticipated effect of ultimately impairing capabilities to slow or limit the spread of damage. (One illustration is the French utility EDF's decision to focus more on laying cables underground, which left them short of pylon reconstruction and maintenance staff when the windstorms of 1999 struck.)

Undue focus on the immediate and direct consequences of disaster mitigating actions may mean that decision makers lose sight of equally important second-round or delayed effects on other parts of the economy and society. Blake, Sinclair and Sugiyarto (2002), for example, suggest that in the case of the recent outbreak of foot and mouth disease in the United Kingdom, the close attention paid primarily to the impacts on agricultural production and farming industries, coupled with the way that the outbreaks were handled (imposition of restricted areas, closed countryside walking paths and waterways, postponed public events, etc.), resulted in the negative effects on tourism outweighing by far those on agriculture. Their model estimates the loss to the UK economy in the order of GBP 2.5 billion in 2001 (of which almost GBP 2 billion are due to declines in tourism expenditures) and predicts further losses to the economy of around 2.2 billion over the period 2002-4 – the vast bulk again due to losses in tourism.

As the example of foot and mouth disease shows, it is also vital to communicate the emerging facts of disasters in the making with trading partners and, indeed, all those who may be eventually affected. This applies *a fortiori* when effective mitigation may require concerted action by more than one country.

Emerging responses

Rapid and reliable telecommunications in the aftermath of a disaster are at the heart of any effective operations to limit its impact. There are useful examples of regulatory and institutional infrastructures for coping with major crises. One is fixed telecom networks, which are generally configured to give priority to emergency calls. This is not, however, the case for most mobile networks. Industry Canada addresses this problem through an emergency telecommunications framework that encompasses a programme for cellular priority access as well as national priority access to dialling, and national and regional committees charged with emergency telecommunications arrangements. Also, it is developing a Telecommunications. Information Sharing Analysis Center for the telecommunication industry and governmental institutions to gather, analyse and disseminate information for the protection of critical infrastructure for telecommunications. In the United States, the Federal Communications Commission has a Telecommunications Service Priority (TSP) scheme and has recently introduced 25 MHz of new spectrum for public safety service interoperability. As in Canada, the national communications system has a government emergency telecommunications service and cellular priority services (OECD, 2000c – although it has to be noted that in both these countries the mobile diffusion rate is quite low compared with most European OECD countries). More generally, it is becoming increasingly important to gain priority access to the Internet and all next-generation networks, thus allowing for greater diversity in establishing secure, online connections in emergencies.

There are also a number of initiatives in place at international level. The United Nations Office for the Co-ordination of Humanitarian Affairs and International Telecommunication Union have a working group on emergency telecommunication. Numerous international agreements exist: the Tampere Convention (drawn up in the 1990s and revised in 2001) addresses provision of telecommunication resources for disaster mitigation and relief operations; the ITU has put together a Disaster Communications Handbook and is actively engaged in persuading its members to sign up to the Tampere Convention; and the International Civil Aviation Organization is addressing standards for aeronautical emergency communications. There are also interesting new international schemes initiated by the business sector – for example, the agreement reached in April 2002 among twelve major Asian telecom carriers (Arcstar) to strengthen disaster recovery measures through such actions as setting up a hotline linking the network operations of all carriers, and creating a manual on handling large-scale disasters and long-term network failure.

Equally, on the medical front the public health aspect of disaster-relief management has been enhanced in the past several years by an ability to rapidly locate and position (by air, if necessary) medical supplies (*e.g.* sterilising and trauma equipment, antibiotics, vaccines, oral rehydration therapy) and field hospitals. But what probably counts even more when disaster strikes is a sound health care system in the first place, particularly in terms of primary health care available to communities. It is the availability of local doctors and allied health professionals who can respond on the spot that makes the difference in terms of saving lives, preventing disability, and halting the spread of disease. Accordingly, checklists have been drawn up emphasising the public health-oriented aspects of disasters (see, *e.g.,* Tulchinsky and Varavikova, 2000).

Beyond these immediate moves to contain the effects of disaster, there is abundant scope for strengthening mechanisms to cope with the longer-term psychological trauma that communities may suffer in the aftermath of disaster. The experience of the Netherlands in this respect is that systematic and professionalised handling of post-disaster disorders can reap considerable benefits. In the aftermath of disasters, the Dutch authorities establish an information and advice centre (IAC), which seeks to gain insights into victims' situations and needs, and which is funded by regular resources and special contributions from central government. A similar organisational and funding structure is now used to organise optimum psychosocial care for the victims, and to monitor their physical and psychosocial problems over a long period (Huijsman-Rubingh, 2002).

What applies to combating the spread of disease in "conventional" disasters is no less valid in respect of new types of systemic threat. There is broad agreement, for example, that any efforts to stem the spread of new infectious diseases or the consequences of bioterrorism rest on the core capacities of the public health system to detect, track and contain disease. In most countries, special responsibility devolves to the regional and local public health authorities and their ability to respond speedily and effectively. There is concern, however, that these public health agencies are not properly equipped for this mission. Local epidemiological capabilities and computer and communications systems are not always adequate, and underfunding seems to be a common cause for complaint.

Some countries are making all-out concerted efforts to rectify these shortcomings. The second phase of the US Centers for Disease Control (CDC) plan regarding the prevention of emerging diseases in the 21st century has set itself ambitious targets for the next few years, not least in matters of disease containment. These include the establishment of a nationwide network for surveillance and response to ensure prompt identification of emerging infectious diseases, and ensuring that state and local health departments have the equipment and trained personnel needed to provide an effective front-line public health response to infectious disease and bioterrorist threats.

Moreover, it is expected that intensive population-based surveillance and research programmes will be set up in at least 10 areas of the United States that will generate data to identify new threats to public health and help guide responses to emerging infectious diseases (CDC, 2000).

6. Cross-sectoral lessons

If major disasters and their consequences are becoming increasingly complex, so too are the operations that need to be set in motion in order to respond to and mitigate them. Equally, however, societies' capabilities for reducing the impact of disasters and for managing the response to them are also increasing as the various tools available – technological, economic, and organisational – improve, albeit sometimes slowly and unevenly. The challenges for the future have much to do with ensuring that those capacities for response keep pace with the complexities that emerging systemic hazards are likely to generate in the coming years.

The level of decision making

In terms of emergency response, a crucial difference between many "conventional" risks and the new emerging risks identified in this chapter is that in the case of the former, both decision making and the response are usually at local level. New emerging systemic risks for the most part require high levels of decision making, notably in government. The challenge is then to ensure that the implementation of measures is devolved to the local level.

The technological implementation gap

While technology may often be at the root of a disaster, it often offers the means for mitigating it. Harnessing the huge potential of new technologies (satellite observation and imagery, remote-sensing, mobile communications, high-performance computing, etc.) for the purposes of more effective emergency preparedness and response will require more than investments in materials and training. Unless a sustained effort is made to ensure that the information and data provided by these technologies are made available in a form that is easily usable by emergency teams on the scene of a disaster, much potential will continue to go unrealised. Moreover, the benefits that technology can bring to disaster management will be considerably constrained if the appropriate policy frameworks are not in place.

Surveillance systems

Effective surveillance is key to timely response and damage limitation. It is not certain that completely new surveillance systems will be required to meet the challenges posed by many newly emerging systemic risks, such as

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infectious diseases and large-scale terrorism. Indeed, the illustrations used in this chapter suggest that there is a preference to build on pre-existing domestic and international structures. However, to the extent that existing surveillance systems are deficient (inadequate reporting, low levels of technical skills, incomplete coverage of regions or of certain types of risk, etc.), identification and tracking of new risks will only be as good as the quality of the surveillance system in place, even though such risks may in fact call for heightened vigilance.

Human behaviour in disaster situations

In preparing, planning and co-ordinating for major emergencies, a case can be made for differentiating organisations' and communities' reactions to certain natural, technology-related and newly emerging systemic disasters. With respect to the latter category, however, it is difficult to anticipate behaviour in the face of crises linked to largely unfamiliar disaster agents, since by definition (with the exception perhaps of such incidents as 11 September) actual experience of them is limited. This would argue for disaster planning and preparedness using forward-looking tools such as scenario generation and analysis.

Generic conditions favouring preparedness

There are limits to the extent to which plans can be drawn up for responding to disasters, since their scale and consequences cannot be wholly foreseen. However, there would seem to be a set of conditions that help to ensure effective emergency planning and co-ordination of response, and which in varying degrees can be applied to most kinds of disaster. By the same token, it would seem that some approaches to planning and co-ordination are superior to others in that they produce clear lines of authority and responsibility, higher levels of preparedness and better results. Beyond a certain point however, planning becomes less effective because the unexpected has to be dealt with, which is only possible on the basis of flexibility and innovative thinking. This is where principles of self-organisation and learning processes may provide pointers for the future. As the broader changes that are unfolding in corporate management, political representation, public administration and elsewhere in society indicate, the key to better preparedness in the area of disaster mitigation and response is likely to be above all a governance issue – involving among other things a greater degree of co-operation and partnership among organisations, public and private, than is generally seen today.

International frameworks for planning and co-ordination

The growing mutli-layered interdependencies linking countries, regions, markets, industries, cultures and so on make it imperative that international responses to large-scale disasters be properly co-ordinated. Progress has been made towards achieving more effective international co-ordination of planning and relief operations through workable frameworks and guidelines. There remain many fields, however, in which international co-ordination is often absent, or restricted to inter-sectoral co-operation with no impact across the board. Moreover, even where guidelines do exist, frequent difficulties are encountered in enforcing them, not least because the question of "who is in charge" remains unresolved.

Responding to "new" emerging systemic risks

Ensuring effective responses to new energy system risks is most often likely to require an iterative process of improvement and adaptation of current structures and procedures. Already with respect to low-intensity risks, important issues of leadership, communication, planning and co-ordination are yet to be resolved in the implementation of many an emergency response system. Until such issues are tackled, it will be difficult to gear up to meet the stiffer challenges presented by large-scale systemic risks.

Annex 1

Characteristics of routine emergencies versus disasters

Routine emergencies	Disasters
Interaction with familiar faces	Interaction with unfamiliar faces
Familiar tasks and procedures	Unfamiliar tasks and procedures
Intra-organisational co-ordination needed	Intra- and inter-organisational co-ordination needed
Roads, telephones and facilities intact	Roads may be blocked or jammed, telephones jammed or non-functional, facilities may be damaged
Communications frequencies adequate for radio traffic	Radio frequencies often overloaded
Communications primarily intra-organisational	Need for inter-organisational information sharing
Use of familiar terminology in communicating	Communication with persons who use different terminology
Need to deal mainly with local press	Hordes of national and international reporters
Management structure adequate to co-ordinate the number of resources involved	Resources often exceed management capacity

Source: Auf der Heide, 2000.

Case Study 1 – Flooding

Flood management and early warning

In terms of emergency management, flooding poses problems both intrinsic and shared with other natural catastrophes. The technical dimension, such as meteorological forecasting and real-time measurement of precipitation and flows, has already progressed considerably and is likely to improve further with contributions from satellite imaging. Improvement is needed, however, in the quality of early warning, communication of information, and understanding of the public's receptivity to flood warnings, calls to evacuate and so on.

Techniques are available today that permit the establishment of surveillance and early warning networks which work well in fairly standard situations (large catchment basins) thanks mainly to improvements in teletransmission networks. The situation is less satisfactory with respect to small catchment basins that are subject to massive, very localised downpours. In the United States, it is estimated that effective early warning reduces damage from flooding by about USD 1 billion. In the Netherlands, the 1993 floods that put an area of 200 km^2 under water along the River Meuse led to the evacuation of 13 000 people; when floods struck again in 1995, better emergency management allowed the damage to be reduced by half compared with 1993, thanks primarily to an improved early warning system.

Often, however, early warning is the weak link in the chain of flood emergency preparations. Frequently the problem is one of the quality of bulletins informing about the impending flood. Once the forecast has been established the information has to be communicated to the authorities, to the emergency services and to the communities concerned, in a form that is sufficiently explicit and clear for the best possible decisions to be made. Hence, the quality of the early warning information is crucial. For example, a multidisciplinary team is mobilised for discharges of the Loire River in France – computer experts, sociologists, hydrological engineers, communications specialists – to ensure that the messages going out to the fire brigade, police, emergency shelters and the public at large are formulated in the most effective possible way, and clearly intelligible to these highly diverse target groups.

Source: Ledoux, 2002.

Case Study 2 – Nuclear Accidents

Radiation protection and emergency management

Following the Chernobyl accident in 1986, the world's nuclear industry carefully reviewed its approach to nuclear emergency planning, preparedness and management. The global effects of the accident graphically showed how important international communication and co-operation are before, during and after such an accident. A nuclear accident anywhere is a nuclear accident everywhere. Since Chernobyl, major international and national improvements have been achieved, and avenues to further improvement continue to be explored.

Internationally, it became very clear that the transboundary effects present major problems to trade, and cause significant liability concerns. Immediately following the accident, the trade of goods, particularly trade within Europe and exports from Europe, were significantly disrupted. No international standard existed defining an "acceptable" or "safe" level of radioactivity in food or other commodities. Nations accordingly adopted standards independently, and the diversity of these caused the interruption of trade across borders throughout Europe. Since that time, international standards have been established defining levels below which food can be traded without the need for radiological protection regulation, although it is recognised that market forces might well stigmatise food and goods from any area affected by large-scale contamination following a nuclear accident.

As there are numerous European nuclear reactors that are either directly on national borders (rivers for example) or are within 10 to 20 km of a national border, another significant transboundary aspect of such accidents is the notification of authorities from neighbouring or other potentially affected countries. Again, at the time of the Chernobyl accident, no internationally recognised mechanism for such communication existed. Very shortly after the accident, however, two international conventions were established. One is titled the Convention on Early Notification of a Nuclear Accident, and the other the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. The first of these establishes, through the International Atomic Energy Agency (IAEA) in Vienna, a network of "contact points" that can be reached 24 hours a day, 365 days a year, and that are to be notified in case of "an international transboundary release that could be of radiological significance for another State". The definition of "radiological significance" is left intentionally vague. The notification system established by this Convention began using fax technology, and is now moving toward Web-based technology on secured lines. The accident state is required to notify the IAEA of any such accident promptly, and the IAEA is required to notify all other parties to the Convention.

Experience with the implementation of these conventions has been gained thorough international nuclear emergency exercises organised by the NEA (2001). These have shown that many countries have, in addition to their convention requirements, bilateral or multilateral agreements with many countries, effectively increasing the number of notification and follow-up information messages significantly. This complicates analysis and response. Practical questions of language have also caused some confusion. To address these and other aspects, the NEA developed a strategy for the management of emergency information and data (2000), which is now being widely implemented. The policy-level implications of these lessons have been that more significant resources are needed to assure that the international aspects of a nuclear accident are appropriately addressed.

Source: Nuclear Energy Agency.

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Case Study 3 – Infectious Diseases

Vaccine delivery in case of a major influenza pandemic

In the United States, annual delivery of influenza vaccine to the public has progressed significantly, with vaccination coverage rates (targeted mainly to high-risk groups) reaching record levels in the 1990s. However, a major influenza pandemic (considered by many experts to be inevitable), unleashed by a novel virus, would present the traditional vaccination programme with problems of a different order of magnitude. The Centers for Disease Control and Prevention (CDC) estimate that it could affect up to 200 million people in the Unites States alone, with between 88 000 and 300 000 fatalities and between 300 000 and 800 000 people hospitalised. The challenges facing delivery of "preventive" vaccines would be enormous. The target population would have to be expanded to encompass the entire population; the warning period preceding the spread of the pandemic strain would be quite short; a moderate-to-severe vaccine shortage would be likely (in the worst-case scenario, no vaccine at all in the first phases of the pandemic) since current manufacturing procedures dictate a production lead time of at least 6-8 months before tens of millions of doses come on-stream; and finally, a second dose of vaccine might be required for millions of people a month later.

Should there be a shortage of vaccines, antiviral agents (amantadine and rimantadine, which interfere with the replication process of type A influenza viruses) could be expected to play an important role in prevention and treatment. Their widespread use, however, would in turn pose yet more problems. Currently, supplies of these agents are well below the demand anticipated in an influenza pandemic, so that a maximum of only 500 000 to 3 million people could receive treatment each month during the outbreak. (This points to the need for an assessment of the feasibility of stockpiling the two drugs, which the US federal government is now undertaking.) Moreover, relative priorities have not yet been established regarding population groups to be targeted for treatment in case of supply shortages. And finally, widespread use of amantadine and rimantadine could lead to the widespread emergence of drug-resistant viral strains.

From the point of view of distribution of preventive vaccines and treatments, the logistics of dealing with a pandemic may be very different from those employed for natural disasters. The pandemic is likely to occur in many different areas simultaneously; essential emergency personnel (medical staff, police, ambulance drivers, etc.) will themselves be highly exposed and require priority vaccination, but so also may the workforce involved in maintaining provision of vital infrastructural services such as power, water, communications and transport.

Source: CDC.

Case Study 4 – Terrorism

Economic and financial crisis management after the September 11th attacks

The 11 September attacks inflicted casualties and material damages on a far greater scale than any terrorist aggression in recent history. The destruction of physical assets was estimated in the national accounts to amount to USD 14 billion for private businesses, USD 1.5 billion for state and local government enterprises and USD 0.7 billion for the federal government. Rescue, cleanup and related costs have been estimated to amount to at least USD 11 billion. Lower Manhattan lost approximately 30% of its office space and scores of businesses disappeared. Close to 200 000 jobs were destroyed or relocated out of New York City, at least temporarily.

A number of industries were hit hard. Airlines, many of which were already in mediocre financial shape prior to the attacks, suffered a substantial loss in capital and demand, in the United States and in many other OECD countries. Aircraft manufacturers almost immediately saw orders curtailed. The insurance sector faced a catastrophe of unprecedented severity (see Case Study 4 in Chapter 5). Hotels, restaurants, travel agencies and other tourism-related businesses suffered a sharp drop in demand, in the United States but again, also in many other countries. The attacks destroyed or disabled whole portions of New York's financial infrastructure, with potentially devastating domestic and international reverberations.

Management of financial repercussions

Financial markets were shut down and remained closed until Monday 17 September. The Federal Reserve instantly indicated that it stood ready to inject virtually unlimited amounts of liquidity to avoid payment failures and cascading defaults. The Fed's New York trading desk, operating from its primary emergency backup site, engaged in massive repurchase agreement operations: its holdings of securities under these agreements more than doubled, from an average of USD 24 billion in the preceding six weeks to USD 61 billion on 12 September.

The Fed also lent money directly to banks through the discount window, lifting the stigma normally associated with this facility, and outstanding loans surged from an average of USD 21 million in the preceding six weeks to USD 46 billion on 12 September. Furthermore, the Fed credited deposited checks being cleared through its books before the amounts were deducted from other banks' accounts, extending USD 23 billion in check float on 12 September, close to 200 times the average over the preceding six weeks. It also kept the Fedwire open late into the night to facilitate payment execution. Against this background, the effective Fed funds rate plunged to levels last seen in the early 1960s, reaching 1.2% on 19 September. On the international front, the Fed established or expanded 30-day swap lines with the European Central Bank, the Bank of England and the Bank of Canada – totalling a record USD 90 billion – so as to enable them to provide dollars to their financial institutions. These and other major central banks also provided their market participants with extra liquidity.

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At the same time, along with the Comptroller of the Currency, the Fed urged banks to roll over loans for borrowers facing temporary liquidity problems, indicating it was ready to assist with additional funds. In addition, the Fed temporarily waived the usual fees and penalties on daylight and overnight overdrafts so as to ease banks' problems in managing their reserve positions. Likewise, the rules on securities lending were suspended for a while to make additional collateral available to the markets. Banks were also notified that regulatory capital requirements would be administered flexibly. Meanwhile, the Securities and Exchange Commission exercised one of the emergency powers it was granted in the wake of the 1987 stock market crash by temporarily lifting the limits on the repurchase by firms of their own stock. In many other countries, the supervisory authorities took similar regulatory forbearance measures.

In the days following the attacks, all interested parties worked inexhaustibly to rebuild communication and power connections and to ensure the smooth and timely reopening of markets. As the financial markets and payment infrastructure returned to normal, loans were repaid, and the temporarily bloated balance sheet of the Fed shrank rapidly. By 19 September, repurchase agreement holdings were down to USD 40 billion and discount loans outstanding to USD 2.6 billion. Over the next two days, the effective Fed funds rate moved back up to around 3%. As in previous episodes of financial stress – such as the 1987 stock market crash, the 1998 Russian default and LTCM debacle, and the Y2K scare – the Fed managed to preserve the integrity of the financial system. That said, the fact that banks and securities firms generally entered this crisis with strong capital bases and sound liquidity positions also helped to avoid a systemic breakdown.

Management of macroeconomic impacts

On Monday 17 September, before the reopening of the stock markets, the Fed cut its target rate by 50 basis points at an unscheduled meeting. During subsequent weeks the target rate was brought down in steps by another 125 basis points. The shock and its immediate repercussions therefore seem to have led the Fed to move much further than would otherwise have been the case. The same holds for many other central banks in OECD countries as well as elsewhere. Thus, in the weeks following the attacks, both the Eurosystem and the Bank of England trimmed their policy rate by 100 basis points, while the Bank of Canada reduced its target rate by 175 basis points.

The fiscal stance had started to be relaxed well before the attacks. In the United States, Congress had passed a major package of tax cuts in June 2001, which was estimated to reduce revenues by 0.7 percentage points of GDP in Fiscal Year 2001. Tax refund checks had started to be sent out in late July.

On 14 September the US Congress cleared a USD40 billion supplemental appropriation emergency spending package. At least half of the money was to be used for relief related to the destruction in Manhattan, at the Pentagon and in Pennsylvania. Ten billion dollars were available immediately for emergency rescue and rebuilding efforts, tightening security at airports and other transportation centres and at public buildings, investigating and prosecuting those involved in planning and executing the attacks, and enhancements to national security. A few days later, Congress authorised USD 5 billion in direct grants plus USD 10 billion in federal loan guarantees for the US airlines. The actual outlays, however, were to fall mostly in the fiscal year starting on 1 October and beyond. They contributed to the aforementioned acceleration of public spending in the fourth quarter of 2001. Limited discretionary fiscal stimulus action was taken in other OECD countries, not least because many of them had less room for manoeuvre. State aid was granted to airlines in the European

Union as compensation for the losses resulting directly from the four-day closure of US airspace, but on a smaller scale.*

Following the approval of the emergency package, a variety of proposals were considered for a set of fiscal stimulus measures, including an extension of unemployment insurance benefits, personal and corporate income tax cuts, and other tax relief provisions – involving an injection of up to 1% of GDP. Agreement on the shape of an additional package was not found before March 2002 however, when a compromise was reached on a package worth 0.5% of GDP and consisting mainly of unemployment benefit extension and business tax relief measures.

Overall, the short-term adverse economic impact of the attacks was far less than feared initially, thanks in large part to good economic crisis management. The Federal Reserve, the US Administration and Congress acted quickly to restore confidence, inject liquidity and provide resources to deal with the consequences of the attacks. Lowering the price of credit and temporarily providing vast amounts of liquidity helped safeguard the integrity of the financial system and save firms from bankruptcy, and was perhaps more effective than bailing out firms with budgetary resources. International co-operation, not least at the level of the monetary authorities, also helped.

Source: OECD, 2002a.

* For example, France granted 55 million euros. Rescue financing was arranged for Swissair and Sabena, which went bankrupt.

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Case Study 5 – Food Safety

Anticipating the broader impacts of damage containment measures in the agro-food industry

Simulation models are important tools for gaining insights into the conditions under which a controversial control measure like emergency vaccination might be an economically viable option. The relative merit of emergency vaccination depends to a large extent on how quickly the epidemic could be brought under control without such a measure, and (for an exporting country) whether or not the fact of having used ring vaccination delays the resumption of normal trading. Whether or not emergency vaccination causes additional damage to trade depends on whether vaccinated animals are slaughtered and on the reaction of trading partners if animals are not slaughtered. It also depends on whether the country concerned will in fact have an exportable surplus in the months immediately following an epidemic; if stamping-out and pre-emptive slaughter have been extensive, it may take considerable time before the sector is ready to trade again.

With a simulation model that combines all the relevant epidemiological and economic interactions, emergency vaccination options can be explored under different assumptions in a quasi-experimental context. Whether or not the economic benefits of shortening the epidemic using ring vaccination will outweigh the additional costs is very difficult to assess at the start of an epidemic, when there is much uncertainty about the latent spread of the disease, the virulence of the virus strain, future meteorological conditions and unforeseen logistic difficulties. Suitably designed models can simulate outcomes under different assumptions about these conditions, and can help to identify a dominant strategy. The use of such a model in *ex ante* test exercises can also help train epidemiologists and decision makers in interpreting the incomplete information typically available at the start of an epidemic, so that they are in a better position to make such a decision quickly in a real emergency.

A useful checklist of qualitative criteria for when and when not to use protective ring vaccination during a foot-and-mouth disease epidemic was drawn up by the EU's Scientific Committee on Animal Health and Animal Welfare (Scientific Committee on Animal Health and Animal Welfare, 1999, p. 13). This checklist might be criticised in that it ignores some important stakeholders (although it does recognise potential public reaction to large-scale slaughter of animals). However, its main weakness as a decision tool is that, in any given situation, some criteria *for* as well as other criteria *against* vaccination will be satisfied. A simulation model can explicitly represent most of the criteria, weight them according to the probabilities inherent in the model, and allow the net effect of the trade-offs between different criteria to be quantified in money terms.

Simulations of the economic impact of vaccination reveal important differences between diseases. For example, if emergency ring vaccination were used in a classical swine fever (CSF) epidemic that first broke out in a densely pig-populated area in the Netherlands, the number of cases would be considerably smaller than if stamping-out alone were used (80% less in the case of a medium-sized epidemic) but not much smaller than if pre-emptive slaughter were used to supplement stamping-out (Mangen *et al.*, 2001). Moreover, there are no great differences in the net welfare effect of using emergency vaccination rather than pre-emptive slaughter, even when delayed resumption of trading is allowed for.

Of course, a disease like CSF, which affects just one species that is reared intensively indoors, has relatively little impact on other economic sectors. However, in the case of FMD, the spillover effects onto other economic sectors can be considerable. These impose costs that are directly related to the duration of the epidemic, and there is no offsetting gain for these other sectors if vaccination is avoided. Emergency ring vaccination has been shown to be optimal for an FMD epidemic in certain cases, depending on animal density and the scale of the epidemic.

The picture with respect to emergency vaccination for both these diseases is likely to change when reliable marker vaccines become available, especially if this development prompts changes in the Office International des Epizooties protocols regarding the use of vaccination. The aim of marker vaccine research and development is to enable vaccinated animals to be distinguished from infected or vaccinated and infected animals by the use of an easily administered serological test.

Source: Burrell, 2002; Mahul and Gohin, 1999; Mahul and Durand, 2000; Mangen *et al.,* 2001.

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 EMERGING SYSTEMIC RISKS IN THE 21TH CENTURY – ISBN 92-64-19947-0 – © OECD 2003

ISBN 92-64-19947-0
Emerging Systemic Risks in the 21th Century
Recovery Issues

Chapter 5

Recovery Issues

Abstract. *This chapter focuses on risk management in the aftermath of a disaster. When disaster has struck, and after emergencies have been treated, there is still a lot of scope for minimising the final costs. Society needs to recover from the trauma of disaster as swiftly and smoothly as possible. Liabilities and compensation have to be determined as quickly and equitably as possible. In some cases the availability of affordable insurance coverage needs to be secured. And last but not least, lessons have to be drawn from past inadequacies and failures.*

Executive Summary of Chapter 5

Emerging systemic risks frequently create new challenges for recovery management due to their novelty and to the extent of damage they involve. They can entail considerable indirect costs, mainly through two channels: the disruption of supply in specific parts of the economy, particularly in vital systems such as health and energy; and negative reactions from the public. Special efforts must therefore go into helping economic activity resume and preventing shortages and bottlenecks, and at the same time rebuilding trust and avoiding undue stigmatisation.

In order to ensure that victims receive adequate compensation, most OECD countries have experienced a gradual broadening of the concept of liability in recent years. This has been due to changes in national legislations as well as in international conventions. If these developments continue, they could have major negative consequences in the future, notably a blurring of the notions of negligence and fault, a lack of clarity in law, and a weakening of incentives for risk prevention, normally a primary goal of tort law.

The overall broadening of liability has also raised concern about the availability of third-party insurance. Increases in insured losses due to natural, technological, health-related, and – more recently – terrorism-related disasters have called into question the long-term ability of the insurance industry to continue providing coverage for such risks. The 11 September attacks on New York and Washington illustrated how difficult it gets to provide insurance against emerging systemic risks, which are difficult to predict, offer little scope for diversification, and require huge financial capacity.

This chapter reviews emerging responses to these issues: introducing liability caps; limiting retroactivity in tort law; using insurance pools and financial market instruments; adapting insurance policy conditions; and having recourse to public intervention through the introduction of compulsory insurance for specific branches, the setting-up of public or semi-public pooling arrangements, and the call for the state to act as an insurer of last resort.

*In the aftermath of a disaster, the attention of the public and the media are at their highest point. A window of unique opportunity then opens for improving the knowledge of new risks, for overcoming inertia and resistance in order to improve the assessment and management of risk, and for avoiding the recurrence of similar disasters. This chapter concludes with a brief preliminary set of cross-sectoral lessons for decision makers at the national and possibly international level (*e.g. *for mega-terrorism).*

1. Introduction

As illustrated by the 11 September 2001 attacks on New York and Washington and the August 2002 flooding in the centre of Europe, disasters create disturbances that spread into society and the economy well after the emergency period. This chapter is concerned with the task of limiting these disturbances and helping society resume its normal functioning. Four categories of issues are considered: recovering from the trauma of a disaster, both in economic and social terms; liability and compensation frameworks governing the recovery phase; the consequences of disaster for insurance; and providing feedback to improve the risk management process. Matters such as whether and how to rebuild damaged structures are beyond the scope of the discussion.

The continuing provision of goods and services after a disaster has struck is a major element of resilience. Helping normal activity resume as quickly as possible, especially in vital systems, should therefore be a crucial policy goal. It is also essential to prevent panic, to preserve or restore the public's trust in risk management authorities, and to avoid undue stigmatisation of a region, a technology, a company or a person. Section 2 of this chapter considers how society can best recover from the economic and social trauma of a disaster.

In addition, disaster victims need to be compensated, the cause of the disaster has to be clarified, and possible liabilities for the damage must be imputed. At the same time, as mentioned in Chapter 3, the way in which liabilities and compensations are determined plays a major role in shaping attitudes towards risk prevention. Section 3 analyses issues related to liability and compensation frameworks. As a consequence of these recent developments the insurance industry might be faced with considerable losses and liquidity needs, and decide to modify supply conditions. Abrupt changes in financial portfolios or insurance coverage can seriously destabilise capital markets. Section 4 is concerned with insurance aspects of the post-disaster period.

It is a well-known fact that the aftermath of a disaster is a crucial period for learning lessons, and for developing mechanisms and reinforcing institutions that will help avoid or at the very least help mitigate future disasters. A catastrophic event focuses public attention and increases society's sensitivity for some time, thus creating challenges but at the same time opening a window of opportunity for public as well as private action. The post-crisis period provides a unique opportunity to improve the understanding and management of risk, in particular by overcoming inertia and conflicts of interest.

Section 5 examines how this phase, which many consider is becoming increasingly short, can be used to get to the root cause of a disaster.

Finally, Section 6 derives cross-sectoral lessons for risk management.

2. Recovering from disaster

In considering how to cope with the trauma of a disaster and minimise its indirect costs, this section investigates two major issues: first, helping business continuity, specifically ensuring that activity in vital systems is not disrupted; and second, preventing panic, restoring trust, and avoiding stigmatisation. For each of these issues, the present context, the challenges and some of the solutions that are starting to emerge are described.

The context

One of the most striking features of disasters in the past two decades, already emphasised in this report, is the importance of secondary consequences. For example, the Bovine Spongiform Encephalopathy (BSE) epidemic in British cattle in the late 1980s-early 1990s had few direct consequences in terms of physical harm, but had devastating effects in terms of the public concern it raised (see Case Study 5 on food safety). The initial event usually leads to such indirect impacts through two channels: first, the inability of specific parts of the economy to return to normal functioning; and second, the reaction of the public (or of specific groups in society) that might entail substantial costs in the form of loss of trust in public authorities or undue stigmatisation of a product, technology, etc.

Disruption in the provision of a good or service can have severe consequences, ranging from the loss of a business opportunity to the generation of shortages and bottlenecks. These can substantially increase the economic burden of disasters, as well as their financial cost. In recent years, business interruption has turned out to be a major line of loss for insurers, and premiums have been on the rise. For instance, after the terrorist attacks of 11 September, approximately 12% of insured losses (*i.e.* close to USD 5 billion) were attributed to business interruption.

Even more importantly, persistent disruptions can have dramatic consequences in the case of vital supplies such as health, energy, water, transportation and communication.

On the other hand, society might develop reactions towards a hazard that are out of proportion with its actual severity. This process, which has been termed as social amplification of risk (Kasperson *et alia*, 1988), can generate considerable additional costs. In particular, it can lead to long-lasting aversion on the part of the public (or segments of it) to a specific product, firm, technology or region. This phenomenon is known as stigmatisation (Kunreuther and Slovic, 1996).

Such factors were at play, for instance, after the Three Mile Island nuclear accident, where indirect costs brought about by negative public reactions far outweighed the direct damage due to the accident. In extreme cases, repercussions of an initial event in society can ultimately lead to highly inefficient outcomes, such as the unwarranted shutdown of a whole industry and dependence upon less reliable or more costly sources of supply.

The challenges

Helping business continuity

A recent study among large US-based corporations found that a majority of chief financial officers do not believe their companies are well prepared to recover from a major disruption in core elements of their activity, and less than a quarter think that their current contingency plans are adequate (FM Global *et alia,* 2002).

At the same time, recent hikes in premiums show that insurance, if considered as the sole response to the risk of business interruption, is reaching its limits. As a consequence, corporations increasingly believe that their risk management strategies should aim at ensuring business continuity.

Emphasis on business continuity can be expected to gain momentum in coming years due to the continuing development of international trade, increasing concentration in certain markets, and the generalisation of just-in-time and lean methods of production. Indeed, the economic costs of a single failure increase dramatically in such circumstances (see Methodology Box 1, Chapter 2).

Business continuity throughout society depends to a large extent on the ability to avoid disruption to vital systems such as the health system, water and energy supplies, administration and public security, transportation, communication, etc. However, it appears that the capacity of vital systems to cope with the consequences of a disaster can be overwhelmed by the scale of damage, even in OECD countries. This has been demonstrated by several recent disasters, such as the disruption caused by the storms Lothar and Martin to the supply of electricity in France in 1999, or the paralysis of utilities in dozens of towns and cities after the 1998 ice storm in the northeastern United States and southeastern Canada.

On 26 and 27 December 1999, two successive winter storms hit France which, in addition to causing numerous deaths, casualties and other losses, damaged the nation's electricity grid considerably. Electricité de France, the owner of the country's electricity infrastructures, was faced with a scenario it had not envisaged, since it was not one region but virtually all regions of the grid that were affected. 250 000 kilometres of low-tension lines were disrupted, and thousands of repairs were urgently needed. As a consequence, close to 10 million people, or 17% of the population, were deprived of electricity.

The ice storms that affected three provinces in Canada (especially Quebec) and the four states in the US northeast between 5 and 10 January 1998, caused a dramatic disruption to the supply of electricity which affected nearly 3.5 million people in Canada and half a million in the United States. They also showed the interdependence and vulnerability of critical infrastructures, with severe difficulties experienced in road and rail transportation, in the supply of energy and heating, in financial services, in telecommunications, and even in the supply of drinkable water (Commission Scientifique et Technique Chargée d'Analyser les Evènements Relatifs à la Tempête de Verglas Survenue du 5 au 9 Janvier 1998, 1999).

Preserving trust and avoiding stigmatisation

A large body of literature has been devoted to investigating the role of specific actors in social amplification processes. In particular, the role of the media in shaping public attitudes towards disasters has received significant attention (see for instance Quarantelli, 1991). Naturally, the media's impact on society's response is enhanced in the wake of a disaster, when people are in search of rapid information. Under those circumstances, the way information is framed by the media has been shown to be biased by factors such as the presence of identifiable victims or blameable officials. Specific issues are thus raised for risk management, which have been examined in detail in Chapter 4.

The media, however, can also be conceived as a part of the process of social amplification. It is worth noting, for instance, that the influence of the media is not constant, but particularly strong when other sources of information – such as risk management authorities – face discredit.

At the heart of these broader social processes governing behaviour are feelings of trust and "betrayal". Trust has been described as one of the central channels through which social identities are constructed in late modernity. Giddens (1991) has compared living in this period as "riding a juggernaut", where a variety of everyday fears can be controlled by the development of trust towards abstract systems and institutions. In this context, the reaction to an accident is a feeling of betrayal of trust (Horlick-Jones, 1995). For some, the increasing focus of modern societies on risk regulation even reflects a cultural shift from hierarchical conceptions of society to conceptions based on trust and blame relations (Douglas and Wildavsky, 1982).

The social amplification of risk, and particular features of it such as stigmatisation, are therefore closely linked to public trust in risk management

Methodology Box 1. **Risk perceptions and trust**

Much literature has underlined the importance of trust in the perception that people have of, and the way they react to, risk situations. Social relationships of all types, including risk management, rely heavily on trust. Indeed, much of the contentiousness that has been observed in the risk management arena has been attributed to a climate of distrust that exists between the public, industry and risk management professionals (Slovic, Flynn, & Layman, 1991; Slovic, 1993). The limited effectiveness of risk communication efforts can be attributed to this lack of trust. If the risk manager is trusted, communication is relatively easy. If trust is lacking, no form or process of communication will be satisfactory (Fessenden-Raden, Fitchen, and Heath, 1987).

One of the most fundamental qualities of trust has been recognised through the ages: it is fragile. Typically, it is created rather slowly, but it can be destroyed in an instant by a single mishap or mistake. Once trust is lost, it can take a long time to rebuild. In some instances, lost trust may never be regained. Abraham Lincoln understood this quality: "If you once forfeit the confidence of your fellow citizens, you can never regain their respect and esteem."

The fact that trust is easier to destroy than to create reflects certain fundamental mechanisms of human psychology, sometimes called "the asymmetry principle." When it comes to winning trust, the playing field is not level. It is tilted toward distrust for several reasons.

Negative (trust-destroying) events are more visible or noticeable than positive (trust-building) events. Negative events often take the form of specific, well-defined incidents such as accidents, revealed lies, discoveries of errors or other mismanagement. Positive events, while sometimes visible, more often are fuzzy or indistinct. For example, a nuclear power plant can safely provide a region with electricity for many years. Is this one event? dozens of events? hundreds? There is no precise answer. When events are invisible or poorly defined, they carry little or no weight in shaping the public's attitudes and opinions.

When events are well defined and do come to our attention, negative (trust-destroying) ones carry much greater weight than positive ones (Slovic, 1993).

Adding fuel to the fire of asymmetry is yet another idiosyncrasy of human psychology – sources of bad (trust-destroying) news tend to be seen as more credible than sources of good news. In general, confidence in the validity of animal studies is not particularly high. However, when told that a study has found that a chemical is carcinogenic in animals, members of the public express considerable confidence in the validity of this study for predicting health effects in humans (Covello, Flamm, Rodricks, & Tardiff, 1983).

Methodology Box 1. **Risk perceptions and trust** *(cont.)*

Another important psychological tendency is that distrust, once initiated, tends to reinforce and perpetuate itself. Distrust tends to inhibit the kinds of personal contacts and experiences that are necessary to overcome distrust. By avoiding others whose motives or actions we distrust, one never gets to see that these people are competent, well meaning, and trustworthy.

Source: Slovic, 2001.

authorities. Instinctive responses from the public and/or officials, such as denial of risk and blaming those responsible, can understandably lead to the question of trust being overlooked in the short term. But in the long term only a restoration of trust can lead to optimal risk management by society. And trust is fragile, much more difficult to build than to lose (see Methodology Box 1).

The nature and the history of the trust link between the public and risk management institutions are therefore important factors of social vulnerability that risk assessment and prevention strategies need to take into account. This too can be illustrated by the BSE crisis in Europe in recent years (Case Study 5). One of the most striking outcomes of the BSE crisis is the loss of credibility of risk management and scientific authorities. This is not only true for the United Kingdom, where BSE had been preceded by several other food security crises. It is also the case, for example, with Germany and France after the events in Autumn/Winter 2000, when both countries were shocked by worrying news regarding BSE in the respective domestic herds.

Emerging responses

Preparedness and co-operation to prevent disruption

Three important lessons are being drawn from recent disasters: the importance of planning and preparedness for business continuity; the need for effective mobilisation of all resources available to help recovery; and the role of vital systems and critical infrastructures in recovery.

By contrast with emergency management plans, business continuity models do not aim at responding to a particular hazard but at recovering from a worst-case scenario. They focus, first, on identifying the key parts and functions of a system, and on imagining how these could be affected and what consequences would follow for the entire system (business impact analysis). Second, they help develop alternative responses, and concern resources as well as determining responsibilities in the management of response (strategy development). Finally, they consider how to implement those strategies with an emphasis on preparedness and planning at the operational level, including establishing the appropriate contracts and provisions, and collecting information for the contingency management plans (strategy implementation).

However, as with emergency management, these models emphasise the importance of effective communication channels within an organisation and between co-operating organisations (see Chapter 4).

New partnerships are taking place to address the scale of modern disasters and effectively bring together all resources available to protect and restore critical infrastructures. Regional co-operation is a crucial element, as best illustrated by the above-mentioned examples of ice storms in Canada and winter storms in France. In both cases, in addition to the widely acknowledged efficiency of local operators (*i.e.,* respectively, Hydro-Quebec and Electricité de France), important contributions to recovery were made by non-governmental organisations, private corporations, public agencies, armed forces, and foreign partners. In Canada, American utility companies provided personnel and equipment to aid Hydro-Quebec. In France, 2 000 technicians from 17 countries took part in repair operations following the disaster.

Founding trust on information, education and protection

A variety of complementary strategies have been identified by social scientists in order to address issues of trust and stigma (for a summary, see Kunreuther and Slovic, 1996):

- *Preventing stigmatising events.* Those hazards that entail a possibility of strong public reaction deserve particular prevention efforts. Typical examples include the siting of hazardous facilities, transport of hazardous material and blood banks. If necessary, risk reduction expenditure in such cases should go beyond what a formal cost/benefit analysis would indicate. Identification of such cases and design of appropriate measures can be based on the use of decision analysis tools (see Chapter 2).
- *Reducing perceived risk by generating trust.* Encouraging public participation in the decision-making process and establishing confidence among the various parties affected by risk decisions (along the lines described in Chapter 2) can largely contribute to building public trust in risk management authorities. Informing the public is equally important. However, traditional risk communication, aimed at providing quantitative information on risk, will very often not suffice to deal with exaggerated fears based on affect. In cases where attitudes towards risk cannot be explained by objective assessments or by accepted public values, it might be necessary to educate and desensitise the public.
- *Educating specific actors about trust and stigma.* The way information related to risk is framed and communicated to the public has in some cases been a

powerful factor of social amplification. Naturally, information on risk – as any other type of information – cannot be made uniform or codified. What is warranted, however, is to help major actors in the field have a better understanding of their influence and responsibility in shaping public attitudes towards risk. A promising strategy in that respect is to educate the media and risk managers (from both the public and the private sectors) about the origins and the consequences of stigma.

- *Protecting the victims of stigma*. Providing insurance to those who are affected by a disaster, even indirectly through stigmatisation, is not only a way of ensuring that they will receive compensation (see next section); in many circumstances, it is also an effective way of limiting those indirect damages. Examples include setting a minimal price for houses or for healthy cattle located in a stigmatised area. Indeed, insurance itself is often perceived as a signal for safety. For instance, it can contribute to correcting negative expectations with respect to the price of a property or to the prospects of a technology. If necessitated by existing market conditions, a variety of solutions can be envisaged to provide affordable insurance coverage to the victims of stigma (see Section 4).

3. Liability and compensation frameworks

The influence of tort law and insurance schemes as framework conditions for risk prevention was already mentioned in Chapter 3. This section provides a more in-depth analysis of the role of liability, compensation, and insurance in the management of emerging systemic risks. Some issues that are not specific to emerging systemic risks will not be examined here. These include, for instance, how to measure damage (both pecuniary and non-pecuniary), or the possibility of legal insulation. Instead, the focus will be on two issues of particular relevance to emerging systemic risks: the limits of liability, and the conditions of insurability.

The present situation

In the aftermath of a major disaster, the way liability and compensation issues are addressed influences the public's trust in public authorities and its perception of whether risks are being handled in an appropriate way by society. It is a duty for society as a whole to ensure that victims are indemnified as effectively and fairly as possible. This is usually achieved through tort law, when a liable party can be identified and enjoined to provide compensation to the victims. However, liability and compensation are not necessarily equivalent. It is possible that no party is judged liable for the damage or that, for various reasons, the judiciary cannot impose full redress on the liable party. Other mechanisms such as compensation funds then need to be used. It is also possible that in particular circumstances, society chooses to impose punitive damages (in other words, damages in excess of harm) on an injurer.

Another task is to ensure that persons who have caused the damage pay an adequate price, so that the costs of harmful behaviour are fully internalised in accordance with the polluter pays principle (OECD, 1975). The definition and enforcement of liability are major instruments of risk prevention, as are direct regulations, taxes and subsidies, and provision of information. It follows that inadequate definition or enforcement of liability can lead to under- or over-deterrence of risk-generating activities.

As mentioned in Chapter 3, over the past fifteen years substantial changes in the liability and compensation framework have been experienced in most OECD countries. Indeed, changes in the very way liability is generally understood can be observed in several international conventions and laws. For instance, international conventions regulating marine oil pollution[1] and nuclear power plant accidents (Case Study 2) submit one group of operators – shipowners and nuclear installation operators respectively – to strict and exclusive liability irrespective of fault or negligence considerations, or whether other parties' actions have aggravated the damage or not. In the European context, the 1985 Directive on Liability for Defective Products introduced the principle of liability without fault in Community law. The Council of Europe's 1993 Lugano Convention on Civil Liability Resulting from Activities Dangerous to the Environment also defined a strict liability for environmental damage. However, international conventions and laws have usually aimed at harmonising existing national practices by consensus, and have built on similar provisions in the legal systems of most OECD countries. Indeed, national legislations have substantially shifted in their definitions of and limits to liability, notably in the areas of environmental damage and hazardous substances. These shifts are often motivated by a willingness to improve victim compensation.

The challenges

The ongoing broadening of liability is the result of three developments. First, liability regimes have tended to shift from negligence-based to strict liability (see Methodology Box 2 for a description of both liability regimes). Second, some elements of retroactivity have been introduced in tort law. Third, the risk of causal uncertainty, *i.e.* of situations where the link between the damage and its causative factor cannot be clearly established, has been partly transferred from potential victims to potential injurers.

Some of these shifts have taken place formally; more often however, they have resulted from gradual changes in case law, notably through a broadening

Methodology Box 2. **Negligence rules vs. strict liability**

The economic analysis of law* usually recognises two broad objectives of tort law: sanction (which is the basis of prevention) of harmful behaviour, and compensation of victims. Depending on whether priority is given to the former or to the latter, tort law can be based more on negligence rules or more on strict liability.

A negligence system defines appropriate behaviour ("due care", often specified by case law) and requires conformity to it. It therefore relies on the assumption that any relevant aspect in the behaviour of potential injurers can be observed. Under this condition, the very possibility of being found liable creates a strong incentive in favour of due care. The more effective the system is, the less accidents can be blamed on operators. In the ideal extreme, negligence disappears and risk is reduced to the level considered optimal by society. Victims then need to be covered by direct insurance, be it private or public (*i.e.* social security).

However, optimal behaviour often cannot be fully characterised by courts, or involves costly controls. Toxic emissions, for instance, involve not only the level of care (*e.g.* filtering) but also the level of activity itself. In practice, incentives are seldom effective to the extent that any negligence is ruled out; furthermore, often only part of the information needed to establish eventual negligence is observed by courts, so that determination of negligence can involve some uncertainty.

Under strict liability, on the other hand, the injurer must provide full compensation to victims, regardless of care. Although compensation is the primary aim, it is sometimes argued that it is the only regime creating optimal incentives, as the costs of the risk-generating activity, whether observable or not, are fully internalised, and no control is required. The issue here is whether the costs of a socially optimal (or "residual") risk have to be borne by society, or by the risk-taker.

Moreover, full internalisation of costs is likely to lead risk-averse operators or producers to take excessive care or reduce their activity below the level desired by society (over-deterrence). Therefore, under strict liability, potential injurers have a strong incentive to look for third-party liability insurance coverage. This, in turn, can generate a moral hazard problem. Thus, the effectiveness of strict liability is also faced with the difficulty and costs of observing and controlling harmful behaviour, albeit to a lesser extent than negligence rules.

All in all, neither system can be considered intrinsically superior to the other. The negligence system, backed by first party insurance (either private or public) for "residual" accidents, can be very effective in cases where optimal

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Methodology Box 2. **Negligence rules vs. strict liability** *(cont.)*

behaviour can be easily controlled and the negligence rule clearly stated by law, leaving little room for uncertainty. In cases where under-deterrence would be more costly than over-deterrence (*e.g.* highly dangerous activities), strict liability is preferable. However, when third party liability insurance exists, the moral hazard issue deserves particular attention, not only from the insurance company's standpoint, but also from that of society at large.

* See Posner (1973), Shavell (1987), Kaplow and Shavell (1999) for a brief overview, and Kornhauser (2001) for a critical view.

of what is considered a fault (for instance, when a "duty of care" is imposed, or when the violation of specific safety standards is considered a fault), through a relaxing of the requirement that damage was foreseeable, or through a reversal of the burden of proof.

That last factor is especially important. Burden of proof has a decisive influence on the determination of responsibilities, since causality often cannot be established with certainty in the case of emerging systemic risks. The producer of a good or the operator of a facility often has an informational advantage over consumers or public authorities. At the same time, the willingness of policy makers and courts to protect victims by transferring the burden of proof to potential injurers can entail a dramatic increase in liability. Such an issue arises, for instance, in the presence of background risk: the injurer's action may only have aggravated a pre-existing risk (*e.g.* radiation leading to an increase in the number of thyroid cancer cases), but all of the victims (*e.g.* sufferers of thyroid cancer) are entitled to claim for compensation.

A similar issue relates to "joint and several" liability rules (as applied, for instance, in the United States' Superfund regime). A victim can claim full compensation from any of his/her potential injurers (*e.g.* manufacturers of a defective product), so that any injurer can be held liable for the whole market, regardless of the injurer's market share. Joint and several rules have been claimed to create incentives in favour of mutual prevention of risks by potential injurers. The problem, however, is that mutual prevention entails considerable transaction costs (related to the redress claimed by one injurer from the other), and that joint and several rules might actually lead to over-deterrence.

Even specialists can no longer evaluate the extent of liability with certainty *ex ante,* or more specifically distinguish between negligence and strict liability. Such a situation could end up blurring the very concepts of negligence and fault, as well as generating a lack of clarity in law that might hamper effective risk prevention.

Emerging responses

Liability caps

In some activities, it has gradually become clear that the broadening of liability needs to be balanced by some limitative measures, as operators and producers seem to be bearing too large a risk.

In the international conventions on nuclear accidents and marine oil pollution, for instance, as a consequence of strict liability and channelling, operators face potentially huge liabilities. Moreover, insurance or other forms of financial security covering liability are mandatory. As unlimited liability is probably not insurable (in particular for nuclear accidents, which are an extreme case of high damage/low probability risks), this requirement leads *de facto* to limiting liability. Indeed, in order to reduce the financial burden on operators, the conventions explicitly introduce financial and time limits to liability.

In the same vein, some legal systems have introduced a hardship clause, whereby the judiciary can limit the amount of compensation paid to victims on an *ad hoc* basis.[2]

More generally, liability caps are often proposed as a way to "compensate" for the introduction of strict liability, to ensure that the operator's liability does not exceed its assets and/or that third party insurance will be available, and to avoid over-deterrence of the risk-generating activities. It is also argued that unlimited liability might aggravate supervisory issues, both in the risk-generating industry where the financial burden might lead operators to cut safety expenses,[3] and in the insurance sector where competition in the supply of third party insurance coverage might incite insurers to overlook the capacity issue.

There are, however, two major arguments against liability caps: they do not provide complete compensation, and they may not fully internalise the costs of harmful activities. Financial amounts made available might have to cover a large number of different claims, including environmental, property and infrastructure damage, as well as purely economic losses and physical harm. The resulting limitations can be quite severe, unless additional sources of compensation are found. In terms of incentives, limiting liability can have positive effects from society's viewpoint if it makes third party insurance available and compensates for the operator's risk aversion. If, however – as has been (and in some countries, still is) the case with nuclear activities – liability caps are far below both the capacity of insurers and the value of potential damage, they then act as subsidies maintaining harmful activities above the socially optimal level.

The bottom line solution might be to adopt liability caps when needed but to maintain them at reasonable levels with regard to compensation needs

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and real costs of an accident. Such was the inspiration behind the recent amendments to international conventions on marine oil pollution and nuclear damage (see Case Study 2). An alternative, chosen for example by Germany in the nuclear field, is to keep liability unlimited but to limit the duty to insure. In both cases, supplementary compensation by states is likely to be necessary in case of an accident, reflecting the fact that the activity has been subsidised to a level considered optimal.

Finally, it should be noted that in all such cases, optimal incentives cannot be implemented through tort law due to the magnitude of damage involved in emerging systemic risks. Complementary measures ensuring optimal risk prevention are thus of the utmost importance.

Retroactivity

One of the most powerful arguments against applications of retroactivity is that they might violate one of the fundamental principles of tort law, namely that the prospect of liability should create *ex ante* incentives in favour of prevention. On this basis, the European Directive on liability for defective products has explicitly excluded development risks, whereby a producer could be held liable for damage caused by its activity, even if the damage was not foreseeable when the activity began.

At the same time, however, in the context of fast-evolving technologies (notably in the area of life sciences), it is difficult to ignore the existence of serious potential risks and the need for sound incentives (from the point of view of society) to counter them. Some argue that some kind of retroactive action can hardly be ruled out, and that what is essential is a clear framework for the management of uncertain risks. One might for instance consider that, as long as the possibility of retroactive application of liability in a given area is clearly stated *ex ante* (as, for instance, in the UK Environment Act 1995 concerning the restoration of contaminated sites), incentives exist – but are simply extended from the area of known risks to that of potential risks. In such cases, availability of liability insurance is essential to avoid over-deterrence of innovative risk-generating activities.

4. Insurance issues

The present situation

Insurance mechanisms can – and in effect do, at least in OECD countries – play a major role with respect to both compensation and liability. To the extent that a risk is well identified, first party (or direct) insurance can provide *ex post* compensation to victims. If a party is held liable for damage, insurance can come either in addition to redress via tort law, or replace it. In the latter case, the insurer can then turn to the injurer to claim for compensation. Furthermore, as long as the conditions of insurability are fulfilled, third party insurance can offer coverage against the risk of being found liable for damages. Such insurance can even be made compulsory in instances where the risk-taker would be insolvent in case of accident (his total liability exceeding his total assets). Insurance can therefore help effective prevention by restoring incentives for a potentially insolvent risk-taker (the "judgement-proof" problem). But both direct and liability insurance can also dilute incentives to prevention, causing the well-known problem of moral hazard. In such cases, optimal incentives can be preserved only if the insurer is able to control the level of care of the insured and monitor it through policy conditions.

The overall broadening of liability has raised concerns about the availability of third party insurance. More generally, the trend increase in insured losses due to natural, technological, health-related and – more recently – terrorism-related disasters has called into question the long-term ability of the insurance industry to continue providing coverage for such risks. As made clear by the consequences of the 11 September attacks on New York and Washington for the insurance industry, emerging systemic risks entail several insurability issues: they are often difficult to predict, at least to their full extent; they offer little scope for diversification; and they require huge financial capacity.

The challenges

Current estimations of insured losses due to the 11 September events are close to USD 40 billion, which makes the attacks the most costly man-made event in the history of insurance. It is possible, however, that final loss figures will exceed substantially these estimates, as is often the case in large-scale disasters. The magnitude of third party liability claims in particular remains uncertain at present.

In the wake of the disaster, the insurance industry realised that it might not have the capacity to provide meaningful coverage against terrorism at an affordable rate. Considering the magnitude of potential losses, it was argued, terrorism risk has to be insured by states. In particular, one of the major surprises for insurers was to discover the number of lines involved: life, aviation liability, other liability, aviation hull, event cancellation, workers' compensation, property, and business interruption.

In a climate that was already unfavourable for the US insurance industry, the events resulted in a substantial tightening of markets. Rate increases in aviation soared 400%. Reinsurers declared that terrorism would be systematically excluded from their coverage in the future, at least for

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commercial lines. As no immediate policy response emerged to tackle the insurability issue, the regulatory authority for the insurance industry, the National Association of Insurance Commissioners, authorised clauses excluding loss due to terrorism when the total insured losses exceeded

Methodology Box 3. **The determinants of insurability**

In the OECD countries, losses due to disasters are covered to a large extent by insurance. The principle of insurance is to mutualise such costs between a large number of uncorrelated (or at least weakly correlated) risks (diversification). Insurers need to have reasonable estimates of the probability of occurrence of a hazard and the magnitude of damage for each (type of) risk (predictability). Ideally, risks are "objectively" assessed with the help of historical data on hazard occurrence and the extent of loss, and models incorporating the current or future risk environment. In cases where a risk cannot be precisely assessed, it is still possible to determine premiums on the basis of a subjective assessment (including for instance an "ambiguity premium" which reflects the magnitude of uncertainty), as long as the insurer and the insured agree on such assessment. It might gradually become clear that a risk was wrongly estimated, or that some of its characteristics (hazard, vulnerability, etc.) have changed. Policy conditions then need to be adapted accordingly.

The very existence of insurance can dilute incentives for risk prevention, and lead to an aggravation of risk (moral hazard). If no distinction can be made between low-risk and high-risk profiles within a type of risk, the low-risk population might find the level of premiums unattractive and stop buying insurance (adverse selection). When risks are predictable and adequately pooled and moral hazard and adverse selection are controlled, premium revenues cover losses and finance the insurer's profits on average. However, insurers also need to build sufficient reserves to cope with worse-than-average losses (capacity).

Insurability of a risk depends on the ability of the insurance industry to respond to demand for coverage against it. In a competitive market, premiums decrease (increase) when insurability improves (recedes) in order to maintain the financial balance of insurers. Insurability is therefore closely linked to competition and regulatory oversight issues: excessive profit margins lead to a non-optimal rationing of demand for insurance; too-low premiums imposed by competitive pressures or by regulatory authorities force insurers to withdraw from the market or to face the danger of insolvency. Moreover, insurability decreases whenever one of the above conditions (predictability, diversification, capacity, moral hazard, adverse selection) deteriorates.

USD 25 million, beginning 1 January 2002. In many states, however, such an exclusion is in conflict with regulations or laws regarding fire coverage, worker compensation and life coverage. Furthermore, lack of insurance against terrorism could significantly affect the stability of real estate and capital markets.

Regulatory authorities have expressed confidence in the long-term ability of the industry to provide a market solution for sharing the risks of terrorism efficiently. A prerequisite, however, will be to address the insurability issues brought to light by 11 September, in particular regarding the difficulty of predicting such events, the limited possibilities for diversifying risks, and the huge financial amounts that need to be mobilised in a short time scale (Methodology Box 3). Such problems might well become chronic in the coming years for a number of emerging systemic risks.

Predictability

As emphasised in Chapter 2, most emerging systemic risks are difficult to predict. Damage typically involves uncertain causal relationships, past experience is of little help when it comes to inferring future probabilities of the occurrence and the extent of the damage, and long lead times cannot be excluded. The possible insurance implications of space weather are an interesting case in point (Illustration Box 1).

Moreover, assessment of such risks is often characterised by intense debates and controversies among experts. In many cases, the state of knowledge does not favour a consensus between insurers and parties at risk on an actuarially fair premium. Some argue that this is the reason why insurance for risks related to terrorism or to genetically modified organisms is currently unavailable.

Finally, transfer of the risk of causal relationships to corporations and possibilities of retroactive application of liability make it difficult for insurers to evaluate *a priori* the extent to which a person's liability might be engaged or to determine premiums accordingly. It should be noted, for instance, that following the Clean Air Act Amendments of 1990 in the United States, requiring that chemical facilities develop detailed risk management plans with respect to the production or use of hazardous substances, insurance coverage for such substances was disrupted for several years (Kunreuther, 1997).

Diversifiability

A number of risks nowadays become systemic because of the existence of physical and economic links that expose a large number of individuals to a single hazard. The result is a high correlation among individual risks, which

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Illustration Box 1. **Space weather hazards**

"Space weather" is a phenomenon caused by radiation and atomic particles emitted by the sun and stars. It is determined by the many varied interactions between the sun, interplanetary space and the earth. It not only affects the functioning of technical systems in space and on earth, but also may endanger human health and life.

The effects of this phenomenon are also many and varied; the first observations were made in the mid-19th century, when the United Kingdom's telegraph wires became unusable during two geomagnetic storms in 1847 and 1859.

Our increasingly technology-dependent world is increasingly sensitive to solar activity and changes in that activity. The following effects have been identified:

- Electronic failure during severe magnetic storms. The best known occurred on 13 March 1989: the Hydro Québec power supply system failed and Québec suffered a power cut lasting nine hours. Experts also suspect that a serious train accident (19 fatalities) in early January 2000 in Norway was caused by heightened solar activity (changing a signal track meant to clear a track).
- Immediate and long-term hazards to astronauts and aircraft crews. For example astronauts are not allowed to leave a space shuttle for space walks during solar flares, and flight crews, passengers and on-board electronics are directly exposed to the secondary cosmic rays produced in the earth's atmosphere.
- A clear link has been established between space weather and the performance of electronic components and satellites (*e.g.* loss of orbital control of the Canadian ANIK satellite on 20-21 January 1994 and the solar event of 10 January 1997 caused the loss of Telstar 401 satellite). Consequently the US National Oceanic and Atmospheric Administration publishes data on the Internet on the likelihood of solar flares and geomagnetic storms; CLS (Collecte, Localisation, Satellites), a subsidiary of the French Space Agency, computes daily predictions of solar activity.
- Risks for telecommunications facilities and for systems using radio waves passing through the ionosphere or reflected by it. For example, in 1996 failures were recorded one day in a mobile radio telephone network in a large US state the reason was a solar flare.

While people and technological systems have always been exposed to terrestrial hazards, bringing space weather into the picture opens up whole new dimensions that may ultimately affect insurance through personal injury, property and financial losses.

Source: Frank Jansen, Berlin, Germany; Risto Pirjola, Helsinki, Finland; René Fabre, Zurich, Switzerland (Swiss Re Publishing) and CNES (the French Space Agency).

makes it more difficult for insurers to diversify their risk portfolio. In the vast majority of recent disasters – notably, every time critical infrastructures were affected – most if not all insurance lines experienced heavy losses.

Lack of diversifiability is among the reasons why flood insurance markets remain underdeveloped in most countries. In the future it could affect, *e.g.,* insurance against cyber-terrorism.

In addition, laws and regulations with a retroactive impact create serial correlations among formerly independent individual risks. For example, while instances of container leakage may have been viewed as individual risks, new safety standards for containers can subsequently link them all by regulation.

Capacity

Unless their capacity is sufficient to face a worst-case scenario in terms of disaster frequency and/or magnitude of damage, insurers are under the threat of insolvency. Various solutions exist at the level of individual insurers to cope with capacity problems, including reinsurance, co-insurance or pooling. In the case of nuclear power plants, for instance, national pools have been organised on a noncompetitive basis, and reinsurance is provided by similar pools in other countries.[4]

However, capacity concerns have recently started to affect reinsurance companies and insurance pools alike. In reaction to several shocks in recent years, the whole insurance industry has had to tighten policy conditions and in some cases even suspend coverage. The prospect of a global insolvency of the industry worldwide has even been considered as plausible, if several catastrophic disasters were to occur in a short time frame (*e.g.* a major earthquake or windstorm hitting one of the large urban centres in an OECD country and creating damage in excess of USD 100 billion).

Naturally, the expanding definition of liability aggravates the capacity issue, in particular as it gradually covers items such as environmental damage and pure economic loss, which often constitute a large share of the total cost of disasters.

Other issues

Finally, the broadening of enterprise liability, which sometimes seems to reflect the desire for a "fault-free enterprise", is accompanied by a shift from first-party to third-party insurance, where information asymmetries can be larger. This can induce more severe problems of moral hazard and adverse selection.

Emerging responses

Predictability

With respect to predictability the insurance of emerging systemic risks will be facilitated by future improvements in risk assessment, due to better data collection and modelling, and powerful information and space technologies.

The insurance industry itself can be among the major carriers of such improvements – notably in the area of data collection on emerging risks, where co-operation between insurers (including reinsurers) could be very fruitful. Such co-operation does not necessarily entail collusion and other anti-competitive behaviour, as shown in a recent report by the European Commission (1999).

Financial market instruments

Both industrial operators and insurance companies have been looking for alternative risk transfer mechanisms in recent years, most notably financial market instruments that transform existing insurance contracts into securities. Catastrophe bonds that are based on insurance against a specific natural disaster are one example of such instruments.

For primary insurers, financial market instruments have the advantage of offering an alternative to reinsurance, in particular in the context of a hard market following heavy losses (OECD, 2002). In addition, prices are determined for a period of several years, whereas reinsurance contracts are renegotiated on a regular basis. However, such instruments probably cannot stand as real substitutes for traditional insurance for most risks because of the considerable costs entailed by accurate risk assessment, particularly when harmful behaviour is not fully observable. Therefore, in the future, financial market instruments will probably play the role of a complement to traditional reinsurance, depending on insurance market conditions.

Coverage limitations

Insurers have started to modify policy conditions in order to protect themselves from the trend increase in liability and from the threats of retroactive liability and causal uncertainty. Three types of changes have been observed in that respect: changes in coverage over time, explicit exclusion of certain risks, and increased differentiation of risk profiles.

Liabilities occurring during a policy's period of coverage can be insured following three different systems: under the act-committed system, it is the causative action that must have taken place during the period of cover; under the loss-occurrence system, it is the actual damage; and under the claims-made system, it is the claim to the injurer or its insurer. Due to the increase in so-called long-tailed risks (risks with potential delayed consequences), a large shift from act-committed to loss-occurrence coverage – and recently (at least in Europe), from loss-occurrence to claims-made coverage – has taken place.

Naturally, such a shift protects insurers from exposure to long-tail risks but not the operators, therefore generating risk aversion and insolvency problems. Moreover, insurers might be tempted to quickly end all insurance policies on which previously unforeseen claims can be expected. Therefore, many legal systems are critical of claims-made coverages. Often, however, they have allowed them under particular conditions: an extension of the period during which claims remain admissible; or, an extension of coverage to claims made after the end of the policy, to the extent that the circumstances leading to such claims have been consistently reported to the insurer. Such provisions, along with short policy periods, can help reduce information asymmetries, better differentiate policies, and improve incentives for prevention. It is therefore not claims-made coverage as such that is problematic,[5] but rather sudden changes from one type of coverage to another in cases where insurers realise that they had overlooked the magnitude of risk.

Insurers might similarly try to protect themselves against retroactive changes in liability law by stipulating that the contract ends as soon as the scope of liability is increased through modifications in legislation or case law. The problem, particularly with case law, is that it is seldom clear that a court decision actually increases liability. More generally, a natural response to increased liability is to limit coverage to a well-defined number of risks or to exclude certain specific risks, which then become uninsurable in practice (see the below section on the state as insurer of last resort).

Adapting policy conditions to individual risks and, as a prerequisite, reducing information asymmetries by improving the insurer's knowledge of a risk and of the population at risk also provide defences against adverse selection and moral hazard. For instance, differentiating policies in accordance with mitigation measures against damage caused by natural disasters could prove effective in some cases.

Public intervention

The preceding analysis shows that in some cases, tort law and the insurance industry cannot provide optimal incentives *ex ante* and sufficient compensation *ex post* in the face of catastrophic risks. Public intervention is then needed, and can take several forms: the introduction of compulsory

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insurance for specific branches, a direct involvement of the state as insurer of last resort, or provision of complementary funding for compensation.

In the latter case, government intervention can be organised through a guarantee fund providing compensation above a liability cap, or compensating for the insolvency of an injurer (if insurance coverage is incomplete) or of an insurance company. In very specific circumstances, liability and insurance can be substituted altogether by a general compensation fund.

Such schemes, however, can involve severe moral hazard problems. If harmful behaviour is not totally observable, the risk-taker's incentives for prevention and mitigation of damage are weakened. In some countries, for instance, incentives to avoid building habitations in flood zones have been extinguished by the guarantee of public compensation (Case Study 1). As already emphasised above, public funding of compensation can amount to providing distorting subsidies to a harmful activity. In addition, if insurance companies benefit from information asymmetries, they will be encouraged to have recourse to public intervention whenever inappropriate policy conditions applied in the past later expose them to large losses.

The traditional response to moral hazard is to provide only partial coverage and to leave the individual, industrial operator or insurance company with a partial exposure to risk. In addition, the mixed public/private solution of guarantee funds (or any other form of supplementary funds) seems more adequate than simple state intervention. Finally, the financing of public compensation funds needs to be provided by taxes on the harmful activity in question, if prevention of damage is to be encouraged.

The case of mega-terrorism

Multi-pillar risk sharing-mechanisms as described above, involving insurers, reinsurers, pooling structures, capital markets and possibly governments, should provide an effective answer to the emergence of systemic terrorism risks. However, mega-terrorism (*e.g.* nuclear or biological attacks), typically excluded from standard insurance policies, could entail losses exceeding the capacity of individual states. In that regard, international solutions may need to be considered.

5. Learning lessons from disasters

The present situation

Disasters are followed by a period in which the attention of the public and the media are at their highest point and a window of opportunity for action opens. Experience of harm forces society to re-evaluate risk and the way it is managed. However, such reconsideration can have both positive and negative aspects.

On the positive side, the origins and the consequences of disaster can be investigated and analysed, and thus provide lessons on how to improve assessment and management of risk. Such lessons can be extended to other similar risk areas (or regions). The momentum created in society can help overcome inertia and resistance against reforms in the risk management process. Effective management of the window of opportunity can reinforce citizens' confidence in the way risks are handled, and all in all significantly reduce the chances that the same disaster occurs again in the future.

On the negative side, lessons from past inadequacies and failures can be ignored – especially when it comes to putting them into practice before the window of opportunity closes – and then gradually be forgotten. In the case of exceptional events, several generations can live with the unfounded belief that risks are appropriately managed, until a new disaster occurs. In the case of the 1910 flood of the Seine, for instance, this "backfitting" process was interrupted by the First World War, and a significant number of the hydrological preventive measures designed after the flooding were never implemented.

The challenges

Learning from disasters entails analysing all phases of risk management in the light of experience, and answering questions such as:

- Are there any precursors to the occurrence of a hazard, and how can they be observed?
- Did the occurrence of hazard correspond to earlier assessment?
- How did the disaster spread, and whom did it affect?
- How did people react, and were warning signals received?
- Were there any unexpected factors of vulnerability?
- Which social and economic trends contributed to creating vulnerabilities, and can they be better managed?
- Which protections failed, if any, and why?
- Were there effective incentives to avoid or mitigate risk?

Beyond examination of such questions, however, systematically organising feedback and ensuring that corrective measures are actually taken prove particularly challenging. Case Study 3 shows that in the case of "big" infectious diseases, important lessons have been learned that yield very encouraging results when applied. However, implementing them more systematically continues to prove challenging.

Emerging responses

A variety of tools and institutional solutions have been developed in the past years to help accumulate experience and learn lessons from disasters.

The case of Chernobyl illustrates how risk management can be improved on the basis of information provided by past disasters. Among the lessons of Chernobyl are the needs for evaluation of precursors and for in-depth analyses, the demand for transparency, and – last not least – the notion of safety culture (Case Study 2).

Today, a number of powerful methods have been developed in the nuclear industry for systematic evaluation of precursor accidents including the follow-up of significant safety performance indicators and the establishment of general and plant-specific risk trends from operating experience. Such methods can essentially contribute to an early detection of significant risks. Similarly, transparency in relations among operators, regulatory authorities and stakeholders, and promotion of safety culture, are two major objectives of past and current efforts to improve regulatory effectiveness in the nuclear industry (OECD – NEA, 1998).

The California Seismic Safety Commission is an example of institutionalisation of learning from experience. Such a process is already in place within this Commission. The California Earthquake Hazards Reduction Act (1985) requires the Commission to prepare and administer a programme setting forth priorities and funding sources needed to reduce state-wide earthquake hazards significantly. The 1997 updated version of the plan, entitled The California Earthquake Reduction Plan, took into account lessons learned from several earthquakes, including Kobe (1995). Reports on recent earthquakes, including a database, are constantly being updated by the Commission. Scholars like Geschwind (2001) evaluate the role of the Commission very positively and in some cases see it playing a pioneering role. Several successes have been credited to the Commission in fields such as building codes, promotion of retrofitting programmes and hazard zoning processes.

The Impact Foundation (Stichting Impact) in the Netherlands follows the same objectives (Huijsman-Rubingh, 2002). In the past years, parliamentary inquiries into the Bijlermermeer and Hercules air disasters both recommended the establishment of a national knowledge centre for post-disaster psycho-social care. The Foundation was finally created in October 2002, with the mission of systematically recording and reporting relief activities in the wake of a disaster.

6. Cross-sectoral lessons

In the aftermath of a disaster, special attention needs to be paid to possible factors of social amplification, notably questions of trust and stigmatisation. This in turn can lay an important foundation for addressing future hazards, since greater trust can mean lower levels of perceived risk.

Systematic feedback needs to be organised with respect to risk assessment and management failures revealed by the disaster. Significant progress could be made in two directions: first, in broadening the evaluation of risk management performance from one particular type of disaster to several types; and second, in creating the institutional frameworks through which to learn systematically from disasters.

Liability, compensation and insurance conditions must be tailored to each specific risk. There is no universally optimal tort regime regarding the definition of liability, financial and time limits to liability, the burden of proof, the exclusion of any form of retroactivity, etc. Adequacy of liability regimes depends to a large extent on the severity of risk, the availability of insurance, the ability to control and monitor behaviour, the actual extent of harm, and the financial situation of risk-takers.

Clarity of the regulatory framework, in particular with respect to retroactivity, is essential. Foreseeable conditions of liability are a cornerstone of effective incentives for prevention of damage, as is availability of third-party insurance coverage. Absence of a clear regulatory framework can be the prime factor of over-deterrence of risk-generating activities.

Parallel analysis of insurance and tort law is a major avenue for future research and regulation.

Compensation motives should not overshadow the need to encourage prevention. It is justified to aim at striking an equitable balance between corporations and consumers on questions of compensation. However, doing so is not sufficient. Restoring appropriate incentives should be a major objective for future changes in liability and compensation frameworks.

In view of the risk of several major disasters (terrorism, floods, earthquakes, etc.) hitting one country (or even several countries) in a short period of time, there is a need to look at mechanisms for 1) effectively combining various tools such as insurance, reinsurance and pooling, state guarantees, and new financial tools (CATs); and 2) "internationalising" these tools by pulling them together across several countries.

The concept of business continuity throughout society cannot be applied piecemeal. A high degree of co-operation among public authorities, public and private utilities, private companies, etc. is called for in drawing up contingency plans as well as in applying recovery strategies.

Case Study 1 – Flooding

Insurance against natural disasters: the case of flooding

The stakes involved in flooding disasters are very high. International insurers and reinsurers have calculated that the amount of aggregate annual losses in the world due to flooding have increased eightfold between 1967 and 1997. During the 1990s, the big global reinsurance companies came to realise how risky it was to insure disaster losses on an open-ended basis, and they now provide limited, non-proportional cover.

Experience shows that market mechanisms alone are not sufficient to cover individuals against natural disasters, and especially against floods. The same holds for compensation mechanisms relying on either insurance or government alone. Only hybrid systems involving both the insurance industry and national solidarity – legislatively induced "mutualisation" – are able to furnish adequate cover for flood risk. Their main defect is that they give scant incentive for prevention.

A number of obstacles make it difficult to cover flood risk with the classic tools of insurance. First, it must be possible to quantify projected losses. But where flooding is concerned, there tends to be a lack of statistics. Second, the risks covered by an insurance company must be statistically independent. But with flood insurance, those very risks are subject to a substantial accumulation risk: a flood event generally affects a very great number of policyholders at the same time, making the insurer's commitment difficult to assess and claims extremely costly. Lastly, the fact that flood risk is so localised generates a great risk of antiselection: exposed persons are the only ones who take out insurance. Insurers must therefore cover "bad risks" (*i.e.* losses are certain to occur sooner or later) and, in accordance with the pricing principle (or actuarial neutrality), policyholders have to be charged premiums in line with the reality of their risks. These premiums are often prohibitively expensive, given the level of risk and the small number of insured in relation to the potential claims. Flooding, like other natural hazards, therefore requires an appeal to another principle – that of solidarity.

In France, for example, there is a debate over whether minor flood events should be left to the insurance industry and recourse to national solidarity reserved for major events, while ways are sought to make economic stakeholders take greater responsibility for risks.

Can prevention be encouraged without imposing financial sanctions for non-prevention? Does generous national solidarity tend to relieve people from a sense of responsibility? One of the principles of insurance is that of incitement: insurance contracts should incite people to behave prudently so as to reduce risks. But how can the system incorporate incentives for prevention without ultimately creating a situation in which premium differentiation would be excessive, once again causing coverage for some to become impossibly expensive?

If insurance fails to encourage preventive action, then prevention must be imposed by regulatory means. Regulatory solutions exist in practically all countries, with varying degrees of compulsion. The question that arises is that of the effectiveness, and even more so the enforcement, of that regulation. For example, one-third of the damage unleashed by Hurricane Andrew (in the United States) was due to noncompliance with building codes. Total losses reached some USD 30 billion, two-thirds of which were met by insurers.

The solution therefore hinges on a subtle balance between the incentive effects of insurance and effective regulation, the enforcement of which requires closer supervision and tighter sanctions.

Source: Ledoux, 2002.

Case Study 2 – Nuclear Accidents

Lessons learned from the Chernobyl accident

On 26 April 1986 the Chernobyl nuclear power station, located in the Ukraine about 20 km south of the border with Belarus, suffered a major accident that was followed by a prolonged release into the atmosphere of large quantities of radioactive substances. The specific features of the release led to a widespread distribution of radioactivity throughout the northern hemisphere, mainly across Europe. A contributing factor was the variation of meteorological conditions and wind speeds and directions during the period of release. Radioactivity transported by the multiple plumes from Chernobyl was measured not only in northern and southern Europe, but also in Canada, Japan and the United States. Only the southern hemisphere remained free of contamination.

This had serious radiological, health and socioeconomic consequences for the populations of Belarus, the Ukraine and Russia, who still suffer from these consequences. Although the radiological impact of the accident in other countries was generally very low and even insignificant outside Europe, the event had the effect of increasing public apprehension the world over about risks associated with the use of nuclear energy. Much trust in governmental and industrial organisations and processes was lost.

The Chernobyl accident was very specific in nature; it should not be seen as a reference accident for future emergency planning purposes. However, it was very clear from the reactions of the public authorities in the various countries that they were not prepared to deal with an accident of this magnitude, and that technical and/or organisational deficiencies existed in emergency planning and preparedness in almost all countries.

The lessons that could be learned from the Chernobyl accident were therefore numerous and encompassed all areas, including reactor safety and severe accident management, intervention criteria, emergency procedures, communication, medical treatment of irradiated persons, monitoring methods, radio-ecological processes, land and agricultural management, public information, etc.

Probably the most important lesson learned was the understanding that a major nuclear accident has inevitable transboundary implications, and its consequences could affect, directly or indirectly, many countries even at large distances from the accident site. This led to an extraordinary effort to expand and reinforce international co-operation in areas such as communication, harmonisation of emergency management criteria and co-ordination of protective action (see Case Study 2 in Chapter 4).

On a national level, the Chernobyl accident also stimulated authorities and experts to a radical review of their understanding of and attitude to radiation protection and nuclear emergency issues. This prompted many countries to establish nationwide emergency plans in addition to the existing structure of local emergency plans for individual nuclear facilities. In the scientific and technical area – besides providing new impetus to nuclear safety research, especially on the management of severe nuclear accidents – this new climate led to renewed efforts to expand knowledge on the harmful effects of radiation and their medical treatment and to revitalise radio-ecological research and environmental monitoring programmes. Substantial improvements were also achieved in the definition of criteria and methods for informing the public, an aspect whose importance was particularly evident during the accident and its aftermath. All these actions have been useful in terms of regaining some of the lost public trust.

Another lesson of policy significance concerns the reclamation of contaminated land. Measurements have shown that contamination, particularly in forest environments, has tended to affect ecological stability. While it was previously thought that contamination levels would decline due to natural removal processes, this has not proved to be the case generally; policy makers will be forced to deal with such problems for longer periods than first thought.

The effects of the accident on public health have also resulted in several valuable lessons with regard to recovery after an emergency and the regaining of public trust. Initially, radiological scientists predicted increases in cancer and other radiation-related diseases for seven to twenty years following the accident. There has as yet been no observed increase in cancer, excepting thyroid cancer. However, the early appearance of the increase in thyroid cancer was initially treated with scepticism, because the "standard model" predicted such cancers much later. It was eventually shown, and has been universally accepted, that this increase is due to exposure to the accident. The lesson here is that a reasonably precautionary approach based on actual observations, irrespective of presupposed models and assumptions, can build rather than deteriorate public trust. Similarly, in the affected regions of Belarus, the Ukraine and Russia, many health effects not related to radiation have appeared since the accident. Originally labelled as "radiophobic overreactions", it is increasingly clear that the extensive social and cultural effects of the accident (relocations of populations, destruction of the social fabric of "village" life on a wide scale, problems related to contamination in the everyday life, etc.) have created significant stress in the affected populations, which is manifesting itself in the form of real effects on health. These "accident-related" effects are likely to occur in any large-scale accident (nuclear or otherwise). Addressing them in an appropriate manner is essential to rebuilding trust in governmental organisations addressing the long-term recovery from the accident.

These socio-cultural health effects have highlighted the importance of stakeholder involvement in the development of approaches to living in the contaminated territories. The policy lesson has been that stakeholders – local, regional, national and international – must be involved, at the appropriate level, in decision making processes in order to arrive at accepted approaches to living with contamination. Such approaches need will to be long-lasting and to evolve with changing local conditions.

The international nuclear liability regime

The liability regime for transboundary nuclear damage is principally based on two major international conventions set up in the 1960s and gradually reformed since. Elaborated in 1960 under the auspices of the OECD, the Paris Convention was meant to shape a regional liability regime in Western Europe.[6] In 1963 it was joined by the Brussels Convention in order to increase the regime's capacity for providing compensation, based on direct contributions by states. The Vienna Convention, elaborated in 1963 within the framework of the International Atomic Energy Agency, was inspired by similar principles, but had a broader geographical scope.[7]

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These Conventions channel liability to the operators of nuclear installations. This means that the responsibility of other parties that might have contributed to damage is not taken into account. Channelling has two objectives: first, to ensure that the supply of goods and services to nuclear installations will not be deterred by the prospects of overwhelming liabilities; second, to systematically enable victims to sue an identifiable party. In addition, the operator's liability is strict (or objective), *i.e.* it covers damage whether negligence or fault is established or not. The only exceptions relate to damage due to armed conflict, invasion, civil war, or exceptionally severe natural disasters. This apparently broad liability regime is, however, subject to limitations. As underlined by Faure and Hartlief (2001), "the victim can only base his suit on the statutory liability" deriving from the convention, and "the right of a victim to bring a suit under the common tort rule of negligence" is excluded. Liability is limited in time, as actions must in general be brought within ten years from the date of the incident. Finally, the possibility of imposing financial ceilings on liability is left to the discretion of state parties, as long as such ceilings are not lower than a determined amount.

Reforming the international nuclear liability regime

After the 1979 Three Mile Island and 1986 Chernobyl accidents, the international nuclear liability regime was subject to widespread criticism, in particular pertaining to its restrictive definition of nuclear damage, the existence of financial liability caps, and to its geographical scope.

Nuclear damage was defined in a rather narrow sense in the 1960 Paris Convention and the 1963 Vienna Convention. It covered loss of life, injury, and loss of or damage to property, and left it to competent courts to judge whether claims resulting from any other kind of loss were admissible. It has been frequently argued that such a definition might lead to overlooking prevention costs, economic losses and damages to the environment, which – as Three Mile Island and Chernobyl demonstrate – can add up to a substantial share of the total cost of an accident. While the willingness to improve the coverage of such costs was shared by an increasing number of countries, wide discrepancies between the definitions and interpretations used in various national legislations offered little room for doing so.

Regarding geographical scope, the international liability regime is pulled between the two conflicting principles of territoriality and universality (Hamilton, 2000). The "universal" view states that a country undertaking a risky nuclear activity must bear all of its costs, in particular those due to damage from contamination, wherever it is suffered. By contrast, according to the "territorial" view, countries that enjoy the benefits of compensation must also bear the contractual duties. This latter standpoint was predominant in both the 1960 Paris Convention and the 1963 Vienna Convention, which both provided a right to legal redress only for damage suffered within the jurisdiction of a contracting state or on the high seas.

Finally, both the Paris and Vienna Conventions provided for a limited liability amount, but in practice made it possible for national legislations to impose higher liability limits. With the ceilings applied in some countries,[8] the actual amount available for victim compensation was several orders of magnitude below the damage likely to be caused by a large-scale accident. In addition, a broadening of the definition of nuclear damage and of the geographical scope of liability entailed a substantial increase in the financial amounts available to cover liability.

To address such shortcomings, reforms of the international nuclear liability regime have been engaged since the end of the 1980s. In 1988, the Paris and Vienna Conventions were linked by a Joint Protocol, whereby the provisions of each Convention apply to all signatories of the other. In 1997, a Protocol to amend the

Vienna Convention was adopted, involving major changes regarding the definition of damage, liability limits, and geographical scope.

The concept of nuclear damage has been enlarged to include economic loss, the cost of measures to reinstate a damaged environment, and the cost of preventive measures, as long as they are believed to be reasonable and to the extent determined by the law of the competent court. This broadening of the definition represents a major reconsideration of the scope of liabilities and warranted protection in nuclear activities. At the same time, it leaves substantial margins to national authorities regarding practical interpretation.

Under the Protocol, a state is allowed to exclude from compensation damage suffered in another state, only if the latter has a nuclear installation in its territory and does not afford reciprocal benefits.

Finally, the minimum level of liability caps was dramatically raised (to 300 million Special Drawing Rights), and a Convention on Supplementary Compensation was adopted.

The Paris and the Brussels Conventions are also undergoing a process of revision which has similar aims and, without excessive prejudice as to its final outcome, might yield results similar to the Protocol amending the Vienna Convention (Rustand, 2000). The minimum liability cap should be raised, in the Paris Convention, to 700 million euros, so as to reach a total amount of 1 500 million euros, resulting from application of the different tiers of the Brussels Convention. One point is still pending. It concerns the jurisdiction and is due to the fact that the European Commission has, in adopting the European Council Regulation No. 44/2001, acquired exclusive external competence with respect to the negotiation and adoption of jurisdiction provisions in international agreements.

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Case Study 3 – Infectious Diseases

The ongoing battle

The challenge that will be posed by epidemics in the 21st century is huge by any standards. Quite apart from the possible emergence of new infectious diseases, many of the more familiar ones such as tuberculosis and malaria are likely to prove difficult to control. In part this may be due to such factors as shifts in climate and growing antimicrobial resistance. However, what will also prove a powerful multiplier of some infectious diseases, including tuberculosis, is their interaction with HIV/AIDS, itself projected to increase strongly in the coming decades. The past, however, is a guide to the fact that infectious diseases can be successfully combated and the tide turned within communities or within whole countries. In the 20th century, smallpox was eradicated and major inroads were made against tuberculosis, and over the last four decades public health efforts to reduce malaria have been remarkably effective in South East Asia and Latin America.

At the start of this century, no fewer than nine infectious diseases have been targeted by the international community for eradication or elimination: poliomyelitis, guinea worm disease, leprosy, lymphatic filariasis, onchocerciasis, Chagas disease, measles, trachoma, and neonatal tetanus. In many cases, these goals have been made possible by the development of new drugs so safe and powerful that they can be administered, with little medical supervision, to all at-risk populations.

If there is one single important lesson to be learned from the past struggle with infectious diseases, it is that there is rarely a single "silver bullet" solution. Rather, successful programmes tend to stem from a combination of efforts on a multitude of fronts: strong public health systems; adequate funding for retaining qualified staff and maintaining availability of medical supplies; effective prioritisation of health care spending; cross-sectoral collaboration between health services, education services, and regulatory and legal authorities; extensive health care coverage; public preparedness; and a strong political commitment. In addition to this, factors such as geography, infrastructure and land use can also play an important part.

Malaria is a case in point. Important gains were achieved in the 1950s and 1960s. Malaria was eradicated or controlled in low-infection ecological zones – *e.g.* subtropical areas of southern Europe, Mauritius, Singapore, Hong Kong and parts of Malaysia. The lesson then, equally valid today, is the importance of strong, accessible health care systems for keeping the disease in check, through both prevention and treatment, and working closely together with local communities. The success story of Vietnam illustrates the lesson. Within a four-year campaign in the 1990s, the number of deaths from malaria was reduced by 90% through a combination of government commitment, additional funding, low-cost interventions and efforts of local health workers. But growing resistance of the disease to drugs is set to again make endeavours to control malaria problematic in the coming decades. This will call for new knowledge, products and tools, and higher levels of investment in vaccine development. These advances in turn will have to build on the lessons of the past, with economic and epidemiological research ensuring that cost-effective mixes of promotion, prevention and treatment are adapted to the specific environmental, economic and cultural circumstances of the populations affected.

Source: WHO, 1999.

Case Study 4 – Terrorism

Insuring risks related to terrorism after 11 September

The 11 September 2001 terrorist attacks on New York and Washington affected the insurance industry on an unprecedented scale. In reaction, most industry players declared mega-terrorism risks "uninsurable", and coverage for losses related to terrorism was suspended in the United States. Such reactions had already been observed in the past, for instance after the occurrence of large natural disasters. Each time, however, the insurance industry eventually managed to find innovative responses to new risks, replenish capital and restore profitability. In the case of mega-terrorism as well, new solutions are starting to emerge – but they might entail an enhancement of the role of states in ensuring the availability of insurance, in particular through international co-operation.

The attacks' impact on the insurance industry

One year after the events of 11 September, insured losses caused by the attacks were evaluated in the range of USD 40 billion to USD 50 billion. The final loss figures are still uncertain, in particular concerning third party liability claims. What is certain, however, is that the attacks are by far the most costly one-day event in the history of insurance, more than doubling the previous loss maximum following Hurricane Andrew in 1992.

Before the events, the risk of major losses due to terrorist attacks was considered so remote that terrorism was generally not subject to a separate line of insurance, and was not even mentioned in most contracts. After 11 September, the immediate reaction of the insurance industry was to provide assurance that exception clauses (such as "act of war") would not be invoked, and that sufficient reserves were available to cover the claims. A variety of policy lines were affected: liability (34% of total estimated losses), business interruption (25%), property (21%), workers compensation (9%), life (7%), event cancellation (2.5%), and aviation hull (1.5%) (Hartwig, 2002). The events occurred in an already difficult context for the industry, and rapidly led to a substantial tightening of markets. Insurance companies were expected to raise up to USD 20 billion of new capital. Large rate increases were experienced, up to 400% in aviation.

Reinsurers declared that terrorism would be systematically excluded from their coverage in the future, at least for commercial lines. Primary insurers in turn started to withdraw coverage for future losses. Most industry actors claimed that, with regard to its unpredictability and to the magnitude of damage it could cause, mega-terrorism was uninsurable.

Regulatory authorities acknowledged that in the present conditions, mega-terrorism constituted a case of market failure, and that at least in the short term some form of backstop mechanism by the federal state was needed. When it came to the precise forms of the scheme, however, many issues were debated: What definition of terrorism should apply? To what extent and for how long should public funds be committed? Should the industry's participation be mandatory or voluntary? What thresholds would trigger recovery for insurers? As no option received the approval of Congress by the end of 2001, the National Association of Insurance Commissioners authorised clauses excluding loss due to terrorism when the total insured losses exceed USD 25 million – a very low ceiling compared to many property values (United States National Association of Insurance Commissioners, 2001).

Costs associated with the lack of insurance coverage

For months after the attacks, terrorism insurance was either unavailable or very expensive and restrictive (in terms of deductibles, coverage limits and other conditions). Although some firms engaged in alternative forms of insurance (pooling with similar firms, multi-layered arrangements with several insurance companies), it was estimated that a large part of demand for terrorism insurance was not satisfied, and that the situation could worsen as primary insurers gradually managed to exclude terrorism from existing contracts (Joint Economic Committee, 2002).

Lack of coverage for terrorism, apart from running counter to many state regulations or laws (regarding fire coverage, worker compensation and life coverage), entails a number of costs and risks. It can have a depressive impact on economic activity, as some companies cannot find financing arrangements and are forced to go bankrupt. Lending to commercial real estate, for instance, had already been restricted in the first months of 2002. Even companies that do find insurance coverage for terrorism face dramatic increases in their premiums, and therefore rising operating costs.

Most of all, many activities and assets are now directly exposed to the risk of other terrorist attacks. For example, it was reported that the Golden Gate Bridge, with a replacement value of USD 2.1 billion, currently has no coverage against damage due to terrorism (McLaughlin, cited by Joint Economic Committee, 2002). If other attacks were to occur, many organisations and individuals would lack the resources to rebuild and restart their normal business or life. This prospect can in itself act as a drag on economic activity.

The lack of insurance coverage for risks as large as mega-terrorism can have substantial economic costs, and needs to be remedied as quickly as possible.

Predictability and capacity issues and solutions

There are two challenges involved in sharing the risks of mega-terrorism efficiently: predicting the likelihood of such events and their consequences; and having the capacity to cover the losses when they occur.

The 11 September disaster forced the insurance industry to abandon a number of beliefs regarding the possibility of such an event, the potential magnitude of losses, and the number of insurance lines involved. With little past experience and limited knowledge of the current forms of terrorism, predicting the distribution of the probable maximum loss in the future suddenly appeared an extremely complex task.

Gradually, however, innovative solutions have started to be proposed (Case Study 4 in Chapter 2). In October 2002, three leading insurance service companies presented new models of terrorism risk estimation. It is now likely that the industry will gradually develop the adequate tools for pricing terrorism risk as it does with other risks.

In terms of capacity, 11 September represented a dual shock. First, losses represent a substantial fraction of available capital and reserves: USD 40 billion to USD 50 billion, compared to USD 150 billion of commercial property and casualty reserves (Hartwig, 2002), and 125 billion US dollars of capital on the global reinsurance market (Brown, Kroszner and Jenn, 2002). Second, capacity needs for the future have increased as insurers realise the magnitude of potential losses due to terrorism. Traditional solutions to capacity problems, such as reinsurance, co-insurance or pooling, do not seem sufficient in the case of mega-terrorism.

One additional solution is to transfer insurance risks to international capital markets through securitisation (as, for instance, with catastrophe bonds). Their immense capacity would, in theory, allow the markets to spread the risks among a variety of investors. However, catastrophe bonds have specific limits, due for instance to the cost of accurate risk assessments. With an annual volume of issuance that has been close to USD 1 billion in the past six years, their market is still in its infancy. Therefore, it does not seem likely that a substantial share of terrorism risks could be spread to capital markets in the coming years.

In this context, it is increasingly acknowledged that states might have a role to play as insurers of last resort in the case of major disasters. Some consider that only a temporary government programme is needed to enable the insurance industry to accumulate the necessary capacity. Others think that because of its particular nature, terrorism insurance will need to have at least a layer permanently backed by public funds. Such schemes already exist in, *inter alia,* the United Kingdom, France and Israel.

Eventually, the answer to the insurance challenges posed by terrorism threats might consist in multi-pillar risk-sharing mechanisms involving insurers, reinsurers, pooling structures, capital markets and governments. However, some extreme scenarios such as attacks with unconventional weapons can entail losses exceeding even the capacity of individual states. International solutions may then need to be considered.

Case Study 5 – Food Safety

BSE in the United Kingdom and Germany: stigmatisation and denial

On 20 March 1996 the UK Government announced that the occurrence of ten cases of a new variant of an incurable, fatal neurological malady, Creutzfeldt-Jakob disease (vCJD), was most likely caused by the consumption of beef infected with the BSE (bovine spongiform encephalopathy). What had previously been treated as a disease specific to cattle now became a major systemic risk affecting both animals and humans. The announcement triggered a massive public debate (it received more reporting in the media than Chernobyl) and had a huge, lasting impact on eating habits, on conventional farming practices, and on food safety institutions. Beef consumption fell sharply. The ripple effects of the announcement, however, travelled well beyond the United Kingdom's borders. A survey of German housewives' beef consumption habits, for example, revealed a devastating stigmatisation effect. In October 1994 only 9% of German housewives declared that they did not eat beef. In March 1996 (before the UK House of Commons statement) the figure stood at 13%. By August of the same year, the figure had shot up to 32%. The total cost to the two economies so far runs into billions of euros.

In addition to the financially heavy consequences for the economy, one of the most striking outcomes of the BSE crisis has been the public's fundamental loss of faith – in both countries – in the ability of authorities to cope with issues such as BSE. It must be acknowledged that it was extremely difficult to handle a new disease for which the knowledge base was thin and the stakes very high. All kinds of uncertainty were involved: variability (vCJD affects young people in particular while the classical form affects the elderly); measurement errors (*e.g.* problems of modelling the disease because of its rareness); indeterminacy (assumptions about BSE's origins vary from infection of cattle with the scrapie pathogene to a randomly occurring cattle disease that spreads through feed containing cattle remains); and a genuine lack of knowledge. But other factors also played a role, not least the authorities' denial of BSE as a systemic risk. In the United Kingdom, denial was present at many levels and for understandable reasons. The years preceding the BSE crisis had themselves been crisis years for food policy with two major food scares, listeria and salmonella. Both disease outbreaks led to several deaths and cost the UK state substantial amounts of money for compensation. BSE would have been the third food crisis in a row – a situation that had to be prevented by all means. There was also recognition of a potential risk for humans engaged in the UK trade of live cattle, cattle products (such as meat, milk, semen, tallow, etc.), meat and bone meal (MBM) and other goods of bovine origin, both inside the European Union and beyond.

There followed a period in which the UK Government's official statements on the issue in no way echoed concerns that BSE might constitute a risk to human life. Moreover, dissenting views on the harmlessness of BSE to humans failed to emerge properly, not least because since 1988 the Ministry for Agriculture and Food (MAFF) was able to exercise a virtual monopoly on the infectious material available to research. That monopoly meant that any animal suspected of being infected automatically became property of MAFF. Consequently, if researchers wanted to work with infectious material, they needed not only the necessary facilities to carry out animal experiments but, more importantly, the permission of the ministry to work on the issue. Last but not least, the ministry had to agree to provide the infectious material. Accordingly, any research carried out on BSE was intensely scrutinised and monitored by MAFF. And any publication on the matter required permission from MAFF for publication. This had two consequences. Firstly, the vast majority of research (at least for the early experiments) was carried out inside MAFF's own laboratories or was at least MAFF funded. (This in fact represented two-thirds of UK BSE research.) Secondly, dissenting views emphasising the risk of transmission to man were more or less excluded from the scientific discourse, as they received neither permission to work with the agent nor the material to perform the necessary work.

In Germany, the phenomenon of denial applied not so much to the lack of scientific knowledge or to the complexity of the disease, but to the possibility that BSE might constitute a problem for Germany within Germany's borders. Individual scientists had since the early 1990s recommended establishing a standing committee of scientific experts to devise risk management strategies, but the idea was rejected by policy makers on the grounds that BSE was not present in Germany. When in 1994 a national research group of experts on transmissible spongiform encephalopathies (TSE) was finally set up, its mandate was merely to catch up on international research standards in this group of diseases. As the BSE crisis unfolded in 1996 and during the ensuing period, there were calls – again from individual scientists – to establish a BSE monitoring programme as a precautionary measure. Policy makers rejected these calls too, deeming the programme unnecessary in a country in which BSE was absent. Moreover, when in 1998 the EU made the establishment of a surveillance system a requirement, it took more than a year for the federal government to ensure implementation of the system throughout Germany.

Ultimately, the BSE crisis has led in both countries to measures that are more in line with the principles of resilience-based risk management and more appropriate for addressing a systemic risk. Both countries came to the conclusion that it is indispensable to build "high-reliability organisations for handling uncertain risks". In the United Kingdom, this is now reflected in the Food Standards Agency (FSA). In Germany the future approach will be to separate risk assessment and risk management. Two new institutions will strengthen proper assessment of risks and the development of risk management responses: the Federal Institute for Risk Assessment and the Federal Authority for Consumer Protection and Food Safety. There remains, however, some way to go before all the problems related to the establishment of an effective and resilient system for managing food-borne risks can be resolved.

Source: Kerstin Dressel, 2002.

Notes

1. The 1992 Civil Liability Convention elaborated under the auspices of the International Maritime Organisation.
2. Examples and analysis of the difference between statutory and *ad hoc* limitations are provided in Rogers *et alia*, 1996.
3. It is often argued, for instance, that unlimited liability would constitute an overwhelming burden for eastern European nuclear power plants and that liability caps could thus have a positive impact on their safety, even though costs of potential damage are not fully internalised.

4. Although the theoretical relationship between concentration and competition is ambiguous in the insurance sector, premiums charged by nuclear pools indicate that they might act as monopolies.
5. Introduction of claims-made coverage actually seems to have improved insurability on various occasions, such as environmental liability in Belgium.
6. At the beginning of 2002, signatory states were Belgium, Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden, Turkey and the United Kingdom.
7. At the beginning of 2002, signatory states were Argentina, Belarus, Chile, Colombia, Cuba, Egypt, Israel, Lebanon, Morocco, the Philippines, the Russian Federation, Spain, the United Kingdom and Yugoslavia, and 18 other countries had contracted the Convention.
8. It should be noted that large discrepancies exist among liability caps effectively applied by national authorities: 15 million SDR in Bulgaria, CAD 75 million in Canada, FRF 600 million in France, GBP 140 million in the United Kingdom, SEK 300 million in Sweden, and no cap in Germany.

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EMERGING SYSTEMIC RISKS IN THE 21TH CENTURY – ISBN 92-64-19947-0 – © OECD 2003

ISBN 92-64-19947-0
Emerging Systemic Risks in the 21th Century
Conclusions and Recommendations – An Action-oriented Agenda

Chapter 6

Conclusions and Recommendations – An Action-oriented Agenda

Abstract. *An over-arching conclusion drawn from the analysis in this report is that emerging systemic risks demand a systemic response. This final chapter presents a set of general recommendations for public sector and private sector decision-makers that provide some of the elements for such a response. They are grouped under five major headings: adopting a new policy approach to risk management; developing synergies between the public and private sectors; informing and involving stakeholders and the general public; strengthening international co-operation in all elements of the risk management cycle; and making better use of technological potential and enhancing research efforts.*

Introduction

Over the years, OECD member countries have developed procedures and institutions to protect human health, property and the environment from damage caused by a wide variety of hazards. At the same time, OECD societies have become increasingly demanding with respect to the levels of risk they consider acceptable. In most cases, risk management policies have been successful in reducing risks to these levels. However, as witnessed by a number of recent disasters – ranging from major food-related health crises to the events of 11 September 2001, these policies are now facing new challenges.

The first part of this report described the driving forces that have begun to change the landscape of risk management, or that are expected to do so in the coming decades: demographic changes, including population growth, migration, ageing, and urbanisation trends; environmental changes, notably the wide-ranging impacts of global warming; technology-driven changes, from growing connectedness to specific risks linked to some recent technologies; and finally, socioeconomic changes ranging from rising inequalities to increased concentration in some industries and markets.

The body of the report considered the ensuing challenges for each phase of risk management. First, concerning assessment, it will become necessary to take better account of the natural and human context of risk. In addition to sound risk assessment, the limits of scientific knowledge and value considerations will be of increasing importance in determining the level of risk that is acceptable and the means of reaching it. In this context, it will prove challenging to ensure both the consistency and the transparency of the decision-making process. Second, concerning risk prevention, knowledge and information will have to be mobilised, specific infrastructures better designed and more diversified, and co-operation increased in order to reduce exposure to and increase resilience against specific hazards. At the same time, the framework conditions for risk prevention – the information and incentives provided by laws and regulations – will need to be improved. Third, with regard to the management of emergencies, the report identified challenges in the collection of information, in communication with the media and the public, in the efficiency of rescue services, and in disaster containment. Fourth, the recovery issues considered included maintaining business continuity, restoring trust and avoiding stigmatisation, determining liabilities and providing compensation, addressing insurability problems, and learning

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lessons. For each of these challenges, the report identified emerging responses.

This final chapter draws general recommendations for action from the analysis, under five major headings: adopting a new policy approach to risk management; developing synergies between the public and private sectors; informing and involving stakeholders and the general public; strengthening international co-operation in all elements of the risk management cycle; and making better use of technological potential and enhancing research efforts. These provide elements of a systemic response to emerging systemic risks.

1. Adopting a new policy approach to risk management

Risk management is often narrow in scope. This is sometimes the result of a partial approach that does not consider – usually for practical reasons – a number of relevant factors. One example is assessment of risks related to the release of a hazardous substance into the environment which ignores the lifestyles of exposed populations. Another is emergency planning based on misperceptions of human behaviour. Narrowness can also result from a failure to consider linkages between the various stages of the risk management cycle. For example, liability and compensation rules can be designed and applied regardless of the contradictory impact they might have on incentives to prevent a certain risk. And the occurrence of a disaster seldom leads to an overall re-examination of how risk has been handled up to that time.

Such lack of scope may be heavily penalised in times of significant change in the risk landscape. The challenges ahead clearly call for a new approach to risk management. Specifically, there are three areas in which substantial progress could be made: the overall view of risk; the consistency of risk management; and the coherence of risk regulations.

Recommendation 1: Adopt a broader view on risk

Risk is multidimensional – a variety of factors influence the nature of hazards as well as exposure and vulnerability to them. Such factors are bound to become even more diverse in a world where obstacles to the movement of people, goods, capital and information are reduced while physical, informational and economic linkages are multiplying. Tailoring a given risk policy to the environment in which that risk arises entails integrating, to the extent possible, the complex interactions of these factors.

1.1. Enhance multidisciplinarity in risk assessment and management

In many areas, risk assessment needs to go beyond the traditional approach's focus on probabilities of occurrence and direct consequences. It must take better account of the environmental, human, behavioural and social factors affecting the transmission of and exposure to hazards. In addition, risk management policies have to take into account the effects they are likely to induce. Today, to overlook such linkages is often to blunt the effectiveness of policies, possibly even to render them counterproductive.

In order to broaden the perspective on risk issues, additional emphasis must be placed on bringing together specialised knowledge in every aspect, from "hard" sciences to psychology, sociology and economics. Two important facets of such a multidisciplinary approach are to build more diversified competencies within each component dealing with risk management, and to establish procedures for enhancing dialogue between disciplines.

1.2. Consider communication and levels of acceptance as an integral part of the risk issue

Many recent risk management failures have resulted first and foremost from two major shortcomings: an inability to understand the public's acceptance level for a given risk/benefit situation, and a tendency to consider communication with the public as an issue separate from risk management. Policies need to pay increased attention to the information the public actually has about risks and benefits, and to the way it *is likely to* (rather than *should*) react to a particular measure.

Better integrating communication and levels of acceptance means that risk management authorities must never lose sight of the public's trust as an irreplaceable asset. They must be open to the variety of standpoints on risk, and dialogue effectively with the public. These points are discussed in more detail in Section 4 below.

1.3. Detect changes in the risk landscape early

Those responsible for risk assessment and management also need to be on the lookout for changes in the factors influencing risk. A number of driving forces – from demographic and socioeconomic to environmental and technological – have started to alter the risk landscape, and will continue to do so in the coming years. For example, management of natural disasters, from hazard assessment and insurance schemes to emergency planning, needs to integrate the possible influence of global warming. Industrial safety assessments and regulations should monitor market conditions more closely and, when substantial damage is possible, anticipate their influence on risk.

By assembling the contributions of various bodies of knowledge and by paying more attention to the prospective study of risk, forward-looking assessment should contribute to a more proactive and responsive management of risks.

Recommendation 2: Examine the consistency of policy across risk areas

This report considers a wide variety of risks, from natural disasters (floods, storms, earthquakes, etc.) through infectious diseases, food safety and technological accidents (fires, explosions, crashes, etc.), to malevolent actions assimilated to terrorism (cyber-crime, bioterrorism, catastrophic terrorism). Policies have usually evolved in isolation in these various areas, with little attention paid to the overall allocation of society's resources to risk reduction. As a consequence, major discrepancies are observed in policies towards risk in all OECD countries.

Three recommendations are made to examine and improve policy consistency across risk areas: first, determine – with the help of cost-benefit and decision analysis tools – the optimal level of risk that should be targeted in each case; second, compare risks and define priorities; and third, share lessons and best practices between risk areas.

2.1. Target an accepted level of risk

Reducing risks entails costs as well as benefits. It necessitates the development of human, capital and knowledge resources that come at a price, and might also mean limiting the development of a technology or the exploitation of a resource, thus losing potential benefits. Conversely, it limits damage caused by a hazard and can induce positive externalities, *e.g.* in terms of job creation and growth in specific activities.

In most cases it can be reasonably stated that there is an optimal level of risk, at which costs and benefits of risk reduction are in balance. Sometimes, however, there may be too much uncertainty regarding the possible consequences of a hazard to evaluate the costs and benefits with a sufficient degree of confidence. In addition, the amount of risk that is acceptable can depend upon ethical and social considerations difficult to quantify in terms of costs and benefits. Therefore, while risk policy – as any policy area – needs to be optimised, the process of optimisation has to be broad and flexible enough to consider all pertinent aspects of the risk issue, from the costs and benefits of various measures to the uncertainties and value issues involved.

Such a decision improvement process could provide a road map to decision-makers to identify the level of risk that is acceptable on a case-by-case basis. It could use a variety of tools, from relatively restricted notions such as "As Low As Reasonably Achievable" (ALARA) to more comprehensive processes of cost-benefit and decision analysis. Naturally, a more complete assessment of the risk issue will call for tools that are more demanding in terms of data and time. The choice of analysis must be tailored to the situation: the urgency of decision, the severity of potential losses, the degree of scientific uncertainty, the importance of social controversies, and so on. As explained in detail in the report, the aim of such methods should not be to provide a "black box" solution to risk management but to help bring to light facts, uncertainties and values without overlooking any of the factors of interest to optimal decision making. Stakeholder input is essential in identifying a solution that will be accepted.

2.2. Prioritise risks

The wide discrepancies in what is considered an acceptable level of risk in different areas (or, similarly, the accepted cost of averting a fatality) have been documented in the past decade for most OECD member countries. For instance, many countries show very low risk aversion when it comes to exposure to radon gas inside homes, and at the same time particularly high aversion to nuclear accidents. Such differences might indicate that resources used to reduce risk in one area would be more productive in another.

Even though responsibilities for handling risks are often widely dispersed, the overall resources available are limited and should therefore be allocated as efficiently as possible among the existing risks – whether in a firm, a municipality or a country. This entails comparing, ranking, and prioritising risks. However, as they are a mixed bag of measurable facts, uncertainties and value judgements, risks are not always easy to compare. Methods have been developed in recent years to help overcome such difficulties but again, they must be seen as tools to structure and facilitate public debate rather than as technical procedures to be followed mechanically. Recommendation 8 below deals specifically with public consultations on risk issues.

Such methods would help determine whether disparities in accepted levels of risk result from actual differences in risk features; from uneven states of scientific knowledge; from the variety of societal values involved; or, if they simply pinpoint inefficiencies in the allocation of resources.

2.3. Exchange information and share best practices among sectors

Naturally, each risk area considered in this report has its specificities, and handling each calls for specialised knowledge. At the same time, many management issues are common to a variety of areas, and therefore much could be learned from the exchange of information and identification of best practices across sectors. To take just one example, the nuclear industry has accumulated substantial experience with respect to involving stakeholders in risk decisions. In some countries, consultation processes have yielded very positive results in the siting of radioactive waste repositories. This experience could be highly beneficial to other industries that deal with hazardous substances.

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Many OECD countries have only recently engaged in the cross-sectoral analysis of risks, through the study of transversal issues such as precautionary policies and risk communication. More systematic exchanges, underpinned by adequate institutional frameworks, still need to be organised.

Recommendation 3: Improve the coherence of risk management

Risk management policies also face the challenge of internal coherence. Policy makers can use a wide range of tools to manage risks, including the provision of specific goods, services, infrastructures and information; norms and standards; tort law; insurance and reinsurance regulations; and economic incentives, deriving in particular from taxes and subsidies. Policy efficiency and effectiveness require that each instrument be used in contexts where it has the most impact and supports the action of other instruments. In practice, however, risk policies often lack such coherence.

More attention should also be paid to consistency over time. Risk management can aim at controlling a risk at various stages of its development: when it is a hypothetical possibility, when it is first observed, or when it is well known. As uncertainties are reduced, as factors of risk unfold and social norms evolve, regulations have to be refined and sometimes drastically modified. Such changes can be extremely costly if past regulations become inconsistent.

There would seem to be room for improvement in the coherence of risk policies in three areas at least: first, in gaining a better understanding of regulation concerning each specific risk; second, in increasing co-ordination and exchange of information among the various phases of risk management; and third, in favouring flexible risk policies.

3.1. Achieve better understanding of the overall effect of regulation on each specific risk

It is first necessary to improve our understanding of how the various elements of regulation (or the absence thereof) shape behaviours and contribute to the final risk picture. Complementarity and synergy between instruments such as tort law and insurance, for instance, should be assessed more fully. The ideal situation would be to have a complete description of the regulation regime as applied to each type of risk. Only on the basis of such an improved understanding can a strategy for risk management be defined consistently, and the most appropriate mix of risk policy instruments chosen.

3.2. Increase co-ordination among the various phases of risk management

Second, co-ordination among the various phases of the risk management cycle can be substantially improved. Recent episodes of flooding in Europe showed, for instance, that surveillance systems can send early warnings long in advance, but that these may not be received or treated appropriately by the local authorities and endangered populations, or may not be followed by effective protection or evacuation measures. Too often, even with correct assessments and effective early warning systems, proper contingency plans are not established.

In other cases, the feedback from a disaster is insufficient to help draw lessons for risk assessment, the design of prevention measures, or emergency planning. In the case of emerging systemic risks, it is particularly important to evaluate the extent to which the occurrence of hazard and propagation of damage conformed to expectations and the extent to which they generated new information. More specifically, the occurrence of hazards could lead to an overhaul of the assumptions underlying risk assessments, and bring to light fundamental changes in the risk context. However, if detection and communication of such issues have not been planned for *ex ante*, it is possible that critical information will be lost during the emergency phase. The various components of regulatory regimes therefore need to be evaluated systematically as circumstances or the state of knowledge evolve.

3.3. Favour flexible risk policies

Third, consistency can be better preserved over time by avoiding decisions that might prove too costly to change, especially when they are made with imperfect knowledge of the risk issue. More precisely, risk management decision makers need to recognise the value of keeping options open. This may entail early action, for instance preventive measures to forestall an irreversible change in the environment until its consequences are adequately understood. Conversely, it may lead to the postponement of preventive action, for instance in the case of the development and application of a technology whose risks and benefits are not yet properly measurable.

To heighten temporal coherence, policy makers need to favour flexible – *i.e.* reversible – decisions, with a particular view to enhancing the process of acquiring information and improving knowledge. Flexibility of risk management options is especially important in the case of emerging risks, where uncertainty and the potential for progress in scientific knowledge are high, but also in the case of risk situations that have been experienced for a long time and that might be substantially altered by external factors.

Specific recommendation for further OECD work

It is proposed that the OECD carry out a series of (voluntary) country reviews on risk management. The reviews could encompass the various elements involved (assessment, prevention, emergency management,

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recovery management) in the major risk areas considered in this report. It would focus on the consistency of related policies and on their ability to deal with the challenges, present and future, created by emerging systemic risks, and identify opportunities for improvement and best practices. Quantitative data, aimed at providing a comprehensive picture of risk issues and their management, would be collected. The reviews would start with a pilot study of a limited number of countries, again on a voluntary basis. Ultimately, most or all member countries could be covered, opening the possibility for an OECD Outlook on Risk Management.

2. Developing synergies between the public and private sectors

The roles of the public and private sectors in risk management have been shifting in the past decades, in particular as a result of regulatory reform and privatisation. Direct government control over risk-generating activities has gradually been giving way to softer forms of regulation, while citizens' expectations in terms of risk control seem to have risen. At the same time, the private sector is itself nowadays faced with many of the challenges identified in this report – for instance, when it comes to providing adequate information to the public and gaining trust.

Managing risks efficiently requires adapting to this changing situation and taking advantage of the new synergy potentials between public and private sectors. More generally, direct intervention through safety regulations and other command-and-control schemes is only appropriate when government has a better knowledge of risk than other actors. Centralised risk prevention strategies are increasingly faced with the difficulty of monitoring all decisions and actions inside a complex system, and with the tendency of individuals and organisations to preserve degrees of freedom. Every day in OECD countries, individuals, corporations and local authorities are faced with new risk situations they have to manage without the help of formal instructions. Three broad areas of action are recommended in that respect: getting the incentives right; enhancing the role of the private sector in risk management; and addressing the issue of scale through co-operation and diversity.

Recommendation 4: Get the incentives right

Efforts in favour of risk prevention can be less than optimal in a market economy because of externalities (*i.e.* the costs of risk-generating activities being borne by others) and short-term reactions to competitive pressures and opportunities. It is thus necessary that governments, in parallel with the process of regulatory reform, enhance risk prevention through three types of action: first, correct the disincentive effects of public policies; second, internalise to the extent possible the costs of risk-generating activities; and third, clarify roles and responsibilities in ensuring safety.

4.1. Correct the disincentive effects of public policies

In some areas, tax and subsidy systems create disincentives to risk prevention. Subsidies supporting intensive practices in agriculture, for instance, have been found to be partly responsible for pollution and food safety problems. In many such cases, public authorities are pursuing other objectives and so tend to overlook the negative impacts of policy in terms of increased risks. In the same vein, land-use and transport planning can play a major role in alleviating or aggravating the costs of disasters through their impact on individual behaviour (*e.g.* in the case of flooding).

Taking account of the consequences measures could have for risk behaviour should become a permanent element of policy design in all parts of government. Where evidence is available, these consequences need to be accounted for in a comprehensive cost and benefit analysis of the proposed policy.

4.2. Internalise the costs of harmful activities

As command-and-control modes of risk management lose momentum, an effective way of ensuring that risks are adequately handled by the private sector is to have the cost of damage borne by those who cause it, in accordance with the Polluter Pays Principle ("Risk Imposer Pays"). Most countries have modified tort law in this direction in recent years, notably with the introduction of notions of liability for environmental damage. In other cases, however, liability laws and insurance schemes have been modified with the sole aim of providing better compensation to victims, whether damage is due to neglect or not. Future evolution in tort law should therefore pay increased attention to creating adequate incentives for risk prevention in tort law.

Another concern raised by recent developments in national tort laws is the uncertainty related to so-called development risks, whereby a producer could be held liable for damage caused by their activity even if the damage was not foreseeable at the time they embarked on the activity. In a number of recent cases [*e.g.* the deterioration of the ozone layer caused by chloro-fluoro-carbons, or bovine spongiform encephalopathy (BSE)], the hazardous nature of a private business was established *ex post* in large part thanks to publicly funded research. These cases point to the need for clarification of the legal frameworks concerning a producer's liability and their responsibilities in continuing risk assessment in cases of uncertainty.

Finally, moral hazard issues need to be better addressed. When liability is limited – notably by the status of corporations – mandatory insurance should be the rule; public and private insurance schemes should adapt polices to risk

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profiles more closely. When such differentiation conflicts with social or ethical objectives (in the case of flood victims, for instance), compensation schemes should preserve incentives for risk prevention.

4.3. Clarify roles and responsibilities in safety

Changing regulations and privatisations have given local authorities and corporate management more of a say in defining, implementing and enforcing safety goals and norms. However, roles are not always clearly defined or responsibilities clearly established between operators, their contractors and enforcement authorities. According to *ex post* investigations, this lack of clarity has been partly responsible for several large-scale accidents in OECD countries in the past years.

Precisely defining respective duties and liabilities could substantially strengthen incentives for safety improvements in numerous sectors of activity. This is, for instance, one of the major aims of the ongoing reform of the UK railway regulation system.

Recommendation 5: Enhance the role of the private sector in risk management

At a time of rapidly changing technologies, practices and market conditions, a major challenge for public authorities is to define, apply and enforce appropriate regulations. Co-operation with the private sector could make this task easier and increase regulatory effectiveness.

5.1. Encourage self-regulation as a complement to traditional control measures

Self-regulation should be encouraged as a useful complement to traditional control measures. A number of large-scale accidents in the past few years show that while risk regulations exist, they may be poorly adapted to rapidly evolving operational conditions, or may simply not be implemented. The long-term costs of such accidents for the operators themselves should make it clear that effective regulations are desirable for all parties.

Developing a dialogue between regulators and operators could therefore help to ensure that rules and norms are appropriate, and encourage their application.

5.2. Work in closer co-operation with private industries dealing with risk

Public regulators could better exploit synergies and work in closer co-operation with private industries dealing with risk – standard-setting institutions and certification companies, as well as insurers and reinsurers.

Tools of risk and safety assessment have been developed by standard-setting institutions and implemented in a variety of industries in recent years, as shown by the impact of ISO certification on safety management in corporations. Public/private co-operations can make use of such tools, complemented when necessary by liability law. For instance, if safety norms are necessary but not sufficient for ensuring an optimal level of care, tort law can hold an injurer liable for damage even if they were in compliance with the norms.

There is also tremendous potential for co-operation with the insurance industry, which could for example make more frequent use of public regulations (such as building codes, industrial safety norms, etc.) as a cost-effective way of differentiating risks. In turn, the insurance industry could play a significant role in implementing and enforcing those regulations, thus sharing the public sector's burden.

Recommendation 6: Address the issue of increasing scale through co-operation and promotion of diversity

Scale and concentration are serious challenges to risk management policies. Even in affluent OECD countries, the occurrence of various hazards can – and repeatedly does – overwhelm society's management capacities, be it in terms of disaster response, rapid recovery, or financial coverage of losses. This is particularly true when a critical infrastructure is affected, exacerbating economic and social repercussions. A threefold strategy could address the issue of scale: first, promote diversity; second, increase the scale of society's response capacity; and third, design adequate risk transfer mechanisms.

6.1. Promote diversity through a range of public policies

Diversity is a natural response to risk, since it decreases society's vulnerability to a particular hazard. Public authorities have a variety of means for promoting this response. Infrastructure policy, for instance, could begin to consider vulnerability as a cost factor attached to concentration. Increasing concentration should therefore be submitted to systematic scrutiny from a risk standpoint with, when needed, rigorous requirements with respect to additional safety guarantees.

Public procurement policy and competition policy are other areas where governments could effectively support diversification and combat the heightened vulnerability that may be associated with concentration.

6.2. Improve mobilisation of resources to increase society's response capacity

Increasing society's response capacity is often a matter of better mobilising existing resources to confront larger, more complex, and sometimes new issues. Participation of governmental services and agencies, private partners, and non-governmental organisations in disaster relief and emergency management is a case in point. Improved planning and co-ordination among these various actors could go a long way toward developing societies' capacity for reducing the impact of disasters.

It is probably preferable that efforts to enhance the effectiveness of co-operation begin in the context of known hazards and emergency situations, before being extended to unknown configurations. Adding new management layers and structures to confront emerging risk situations when existing structures do not yet deliver their full potential would no doubt prove less efficient.

6.3. Design adequate risk transfer mechanisms

The capacity of risk transfer mechanisms to deal with emerging systemic risks deserves special mention. The increase in losses due to natural, technological, health-related, and now terrorism-related disasters has raised questions about the ability of the insurance industry to continue covering these risks. Multi-pillar risk-sharing mechanisms involving insurers, reinsurers, pooling structures, capital markets and possibly governments need to be designed in response. In some extreme cases (*e.g.* catastrophic terrorism, earthquakes affecting megacities), in view of the interdependencies between national capital markets and insurance industries, financial loss due to major risks could become a global issue necessitating a co-ordinated international response.

Specific recommendation for further OECD work

The OECD should investigate the issue of capacity-building toward the financial response to large-scale disasters. This work would review the various instruments of risk transfer, including insurance and reinsurance, insurance pools, compensation funds and catastrophe bonds. It would analyse the issue of sufficiency of national capacities; the need for and features of an international layer adding to national schemes; the role of governments in that context; and the merits and limits of various forms of international co-ordination. It could build on the findings of ongoing work on the insurance aspects of catastrophic terrorism, as well as on the Nuclear Energy Agency's experience as the depository of two international conventions on nuclear third-party liability.

3. Informing and involving stakeholders and the general public

One of the crucial aspects of the heated debate that has taken place in the past fifteen years between proponents of a "social" approach to risk management and those favouring a "scientific" approach pertains to the role of government in the public's perceptions of risk. The former school of thought focuses on the value-laden nature of risk, and advocates a representative form of government that would follow and reflect the public's preferences with respect to risk management. The latter emphasises the need to allocate rationally society's limited resources for risk management based on objective assessments, and advocates a preference-shaping form of government that would correct the public's "misperceptions" regarding risks.

The challenge for governments is to strike the right balance between these polar models. In other words, they must avoid founding risk management policies solely on experts' evaluations or, alternatively, on reactions of the public, and instead work with both experts and citizens to prioritise and regulate risks based on sound reasoning. Recommendations for action in this respect fall into two categories: developing risk awareness and safety culture; and enhancing dialogue and building trust.

Recommendation 7: Develop risk awareness and a safety culture

A society's safety culture is a determining factor in the way it prevents hazards, prepares for their occurrence, minimises their impact and recovers. Awareness of risk issues and commitment to their handling among people and organisations is a prerequisite for efficient risk management in an open society. Promoting a safety culture requires getting the various actors in society to understand the different facets of major risks, without neglecting one aspect or overemphasising another. The development of a balanced understanding of the scientific and social aspects of risks and benefits is also essential. It is, therefore, a matter of dialogue and exchange between risk managers and local actors.

Two categories of action are recommended with regard to the promotion of a safety culture: first, educating, training, and communicating; and second, adequately articulating self-organisation and centralised risk management.

7.1. Develop safety culture through education, training, and communication

Very often, the apparent neglect – or, on the contrary, the excessive concern – of the public with regard to a risk represents an inadequate articulation of the risk/benefit balance or its scientific and social aspects. In many risk areas, ranging from floods to neglected infectious diseases, the public needs to be better informed or updated on a hazard, on means of avoiding it or mitigating its consequences, and on individual responsibilities in risk prevention. However, the development of a safety culture requires information not only to be accessible to local risk managers as well as to laymen, but also to be usable and actually used by them.

The media, schools, hospitals, local public authorities and non-governmental organisations can play important roles in this respect. In some

OECD countries, disaster preparedness has long been an integral part of civil education in schools. Others organise large public events related to risk prevention and emergency response (*e.g.* Japan's Disaster Day).

Adequate risk communication is also of particular importance, notably during the window of opportunity opened by an accident or a disaster. Disasters are followed by a period in which the attention of the public and the media are at their highest. The experience of harm forces society to re-evaluate risk and the way it is managed. The origins and consequences of a disaster need to be investigated, analysed and communicated to the public in the form of recommendations for the future before this period of heightened attention ends.

7.2. Articulate self-organisation and centralised risk management more fully

Providing information is adequately carried to local risk managers and the public, principles of community self-organisation may provide important pointers for the future of risk prevention and emergency management. Learning processes and voluntary co-ordination inside networks may provide highly effective ways of developing awareness, preparedness, and responsiveness to hazards. At the same time, however, more centralised modes of risk management remain necessary to ensure coherence of structure and unified leadership.

Adherence to a number of principles can help establish the right balance between centralisation and decentralisation in the handling of risks. First, consensus has to be established among the organisations involved, with each entity understanding the purpose of the network, its own role, and that of the other entities. Second, a leader has to be identified and acknowledged for their legitimate authority and expertise, and has to operate through a central co-ordinating mechanism. Third, the organisations have to maintain frequent contact and interaction in normal times, especially through periodically arranged joint exercises, since establishing consensus and authority structures during the onset of a major disaster is extremely difficult.

Recommendation 8: Enhance dialogue and build trust

In today's world, it is impossible to handle risk without the essential ingredient of trust. When the public does not feel that trust, there tends to be overreaction in the form of panic and stigmatisation of certain products or technologies – indeed, a heightening of risk. The BSE crisis in Europe in the 1990s demonstrated that lost trust can drive a wedge between the "rational" risk policies promoted by experts and the expectations of the public. It also showed that the costs to follow for risk authorities are, in any case, bound to be formidable. Risk management services and agencies should therefore make generating and reinforcing trust one of their primary aims. That will mean building a constructive dialogue between risk authorities and society – all stakeholders should feel that their legitimate concerns receive attention in the decision-making process. Four lines of action can contribute to building this bridge and improving relations. First, ensure credibility of risk assessments; second, develop deliberation processes between risk managers, experts and stakeholders; third, even in emergencies, favour transparent and consistent risk communication; and fourth, identify and effectively correct the causes of failures so as to reassure the public.

8.1. Ensure the credibility of risk assessments

To be credible – thus, to generate the citizens' trust – risk assessments need to have clear and solid grounds, be effectively communicated to the public, and have no link to policy decisions. Institutional arrangements can help establish this credibility. For example, assessment can be entrusted to independent advisory agencies whose personnel are appointed solely according to criteria of competence and integrity and whose decisions are, if not necessarily followed, at least respected by policy makers. In recent years, such bodies have been created or ameliorated in several OECD countries, notably in the field of food safety. Another solution is to systematically submit scientific assessments for peer review – providing the review process is rigorous and transparent – and to make the information available to the public. Such is the procedure followed by the Office of Management and Budget in the United States.

Institutional changes undertaken to reinforce credibility should properly reflect the particularities of the risk category and the country in question. And they should in no way attenuate or mask the responsibilities of policy makers. It must be clear that scientific assessment is only one input among others in decision making, and that the quest for the best scientific expertise should not serve as an excuse to delay, let alone preclude, action.

8.2. Develop processes of deliberation between risk managers, experts and stakeholders

Risk decisions involve a variety of actors, from public officials and experts to interested and affected social groups, each of which might represent a different sensitivity to the various dimensions. Analyses leading to risk management decisions must therefore pay explicit attention to the range of standpoints, in particular in situations with a high potential for controversy. This is often best done by involving the spectrum of participants in every step of the decision-making process, starting with the very formulation of the problem to be analysed.

Deliberative procedures bringing together the stakeholders in a risk issue have been devised and developed in recent years in diverse risk areas and countries, and the experience has yielded a number of lessons and tools. When involving stakeholders, risk managers have to avoid putting a premium on well-organised private interests to the detriment of the general public. Deliberative procedures can be adapted to the specificities of the risk issue, provide lessons in risk communication to the broader public, and be based on objective and scientific assessment. At the same time, however, they have to express clearly the limits of scientific knowledge, the underlying assumptions and the uncertainties. Methods of decision analysis can help determine the role of facts, uncertainties and values in differing risk evaluations, and lead to balanced and efficient decisions.

Foundations such as these now need to be applied more broadly.

8.3. Even in emergencies, favour transparent and consistent risk communication

In periods of crisis, trust cannot be used as a pretext for lack of transparency or adopting paternalistic attitudes towards the public. In OECD societies today, withholding information on major risk issues is generally not practicable over long periods of time, and can be extremely costly in terms of lost public confidence. Only in some exceptional cases where the physical protection of people is involved (*e.g.* terrorism) can a temporary lack of information be accepted by society.

On the other hand, the release of information on risk should be managed in an effective and timely manner. Risk management authorities need to be aware of the social dynamics of risk issues, and of how information can be framed and used by specific stakeholders. All agencies and services dealing with risk communication need to be able (notably through training) to provide a complete and objective view of risk to the public.

8.4. Identify and correct the causes of failure to restore trust

In addition to transparency and effective communication, corrective – and possibly precautionary – measures are necessary to prevent damage from spreading, and to restore the public's trust. In many cases in the past, reactive and inadequate announcements aimed at reassuring the public have only increased confusion and entailed additional costs. Therefore, such measures have to be planned for and implemented in a timely fashion after a hazard occurs, based on an accurate understanding of the actual situation and of the public's perception of it.

Finally, denial should have no place among risk managers' attitudes. One way to ensure this is to avoid the systematic search for scapegoats, *i.e.* apportioning blame on the basis of a superficial examination of responsibilities in the aftermath of disasters. Some OECD countries have begun according more room for manoeuvre to independent bodies investigating accidents and disasters. The generalisation of such professional services is warranted as a means of detecting the real origins of risk management failures, be they individual, collective or organisational, and of restoring public trust.

Specific recommendation for further OECD work

The OECD should explore the development of instruments for assuring the flow of accurate and timely information to governments and stakeholders at national and international level, as well as instruments of reactive and proactive intervention. Particular attention should be devoted to finding means of improving communication with stakeholders and the general public, and strengthening their involvement in the various stages of the risk management cycle. In addition, in specific areas like food safety, nuclear safety, natural disasters and possibly cyber-crime prevention, it is recommended that the various aspects of risk communication and public participation in decision making be reviewed.

4. Strengthening international co-operation

A significant feature of emerging systemic risks is their increasingly international, often global dimension. This holds not only for many of the risks themselves (*e.g.* infectious diseases, terrorism, extreme weather conditions), but also for the context in which they are evolving (*e.g.* growing transborder movements of people and goods, global climate change) and for the solutions available to risk management.

Co-operation among countries, therefore, is of major importance. It can be implemented in various forms and at different levels. In a rough progression from less to more intensive engagement, international co-operation may range from simple exchange of information on and knowledge of the current situation, through agreements on common definitions, norms and objectives, to co-ordination of national initiatives and, finally, to joint action. There can be no doubt that over recent decades considerable progress has been made at all these levels in many areas of risk management. The body of this report has enumerated many such examples. Nonetheless, the report has identified numerous cases where further progress is desirable. The recommendations that follow categorise these cases in three clusters: knowledge transfer, collaboration on monitoring and surveillance tools, and creating broader co-operation frameworks.

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Recommendation 9: Achieve better sharing of knowledge and technologies across countries

New technologies – in particular, high-performance and widely distributed computing, satellite observation and imagery, mobile communications and the Internet – hold out the prospect of significant benefits to risk management if their potential contributions can be realised. But they face a number of obstacles: uneven distribution of specialised knowledge and technological capacities among countries (*e.g.* access to satellite networks, geographic information systems, epidemiological expertise); lack of the requisite technical and organisational skills to benefit from them; insufficient funding; and a frequent inability to furnish practitioners with data and information that are comprehensible and usable.

9.1. Reinforce existing co-operative structures

A wide range of international co-operative platforms for sharing knowledge and technologies already exist. The way has been led primarily by organisations and sectors with long traditions in safety assessment, inspection and information communication (*e.g.* UN Disaster Assessment Committees, the OECD Nuclear Energy Agency and chemicals programme, WHO).

In a number of areas, however, such structures would benefit from further strengthening. This is notably the case with relief efforts directed to regions stricken by natural catastrophes, where poor co-ordination of information and logistics frequently leads to an over- or under-response to the disaster. It also applies to the urgent need to facilitate global flows of data and knowledge among users and providers of disaster management information. Useful initiatives such as the Global Disaster Information Network (GDIN) have emerged in recent years, but need to be strengthened and expanded to meet the growing demands of the next decades.

Finally, in yet other areas, completely new structures for international co-operation may have to be explored, for instance in meeting the global challenges posed by the risks of bioterrorism and cyber-crime.

9.2. Expand information- and technology-sharing agreements to developing countries

Improving the diffusion of knowledge and technologies to the less well-equipped populations at risk – most notably perhaps in developing countries – is clearly a humanitarian objective, but it also serves to reduce the vulnerability of economies and societies more generally. International co-operation is a vital tool in this regard. It should be remembered, however, that the gap in capacity to manage major disasters between advanced and developing countries is considerable.

OECD member countries and international organisations could make an important contribution to closing that gap by exploring further the possibilities for gradually expanding existing information- and technology-sharing agreements to include key players among transition and developing countries. One example is ongoing co-operation in the fields of nuclear safety research and nuclear legislation with Central and Eastern European countries and Russia, under the auspices of the OECD Nuclear Energy Agency.

Recommendation 10: Enhance international systems of surveillance and monitoring

The previous chapters of this report have highlighted the necessity for effective, widely cast surveillance and active monitoring of a diverse range of hazards. When, in this highly interdependent world, the lack of appropriate surveillance structures leads to risks going undetected, or being wrongly assessed or inadequately managed, the chances of contagion or amplification in such areas as health, radiation, terrorism etc. are greatly increased. Several initiatives already in place at international level provide useful leads as to the direction in which actions to strengthen surveillance and monitoring internationally could be encouraged. The fields involved include nuclear energy, telecommunications, chemicals, infectious diseases and antimicrobial resistance. Initiatives in new areas are also emerging.

10.1. Build effective surveillance into pre-existing domestic and international structures, to provide decision makers with usable information

Effective surveillance is key to the timely assessment, prevention, mitigation and limitation of hazards. For many emerging systemic risks, such as infectious diseases and large-scale terrorism, it is unlikely that completely new surveillance systems will be needed. (One notable exception, near-earth objects, is mentioned below.) As the report indicates, there is a widespread preference for building on pre-existing domestic and international structures. However, existing surveillance and monitoring systems do reveal deficiencies – inadequate reporting, lack of appropriate advanced equipment, low levels of technical skills, incomplete coverage of certain regions or types of risk. And ultimately, the identification and tracking of emerging risks can only be as good as the quality of the surveillance systems in place. A further point is that these existing systems generally consist of networked national or regional establishments, so that the integrity of the overall surveillance depends vitally on the quality of the individual participating establishments.

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Many technical information tools are now available to decision makers; what is important is to ensure that the type and timeliness of the information supplied matches their needs. Emergency exercises are useful in this respect. They can help clarify these needs, serve as a training ground for the individuals who will be responsible in case of an emergency, and test-run local, regional, national and international plans.

Apart from relevance, the density of information (geographic, demographic, hazard assessment, uncertainty, etc.) that should be presented on maps to be used by decision makers is a key issue. This information density should be chosen to facilitate rapid assessment of a situation, and should correspond to the types of decisions that will be necessary at that moment: dispatching emergency response units, deciding on countermeasures, asking for international assistance, etc.

10.2. Co-ordinate efforts to strengthen the capacity of public health systems to cope with emerging risks

Improving surveillance and monitoring of systemic risks globally requires action not only at international level but also at national level. Responding to the threat of bioterrorism is a useful case in point. There is broad agreement that ultimately, a country's most effective line of defence against terrorist-initiated attacks in the form of anthrax, smallpox, etc. is a well-organised, well-trained, well-prepared and vigilant public health service. As recent moves by the United States' Center for Disease Control and Prevention (CDC) and the United Kingdom health authorities to improve the monitoring of infectious diseases demonstrate, even highly developed societies need to be aware of their weaknesses in this respect, and to take remedial measures. This requires a well-funded, highly focused effort to bring about the necessary technical, organisational and logistical changes. Such efforts could benefit significantly from regular exchanges of views and experiences among countries on improving public health services' effectiveness in preparing for and dealing with emerging systemic risks.

10.3. Expand the shared use of space technologies for risk surveillance purposes

A number of initiatives have been taken in recent years with respect to sharing space technologies and applications. For instance, in June 2000 the European Space Agency (ESA) and the French Space Agency (CNES) signed a co-operation charter for co-ordinated use of space facilities in the event of natural or technological disasters. Agencies of several other countries have signed in the meantime, and it is recommended that efforts continue to widen participation.

One particular threat calling for this kind of co-operation is that of near-earth objects, a phenomenon that has received considerable public attention in the past few years. Consideration should be given to the kind of international structures that may be needed in order to set up an effective early warning system and to identify possible mitigation measures.

Recommendation 11: Create the frameworks for co-operation

From a broader standpoint, unco-ordinated approaches to risk management may entail considerable costs to the global community. These costs can take the form of underprotection of global common assets due to self-interested behaviour; trade disputes, due for instance to attitudes towards precaution that might conceal protectionist motives; and inefficiencies and gaps in regulation, which may provide unwarranted protection from legal action. International management of a variety of risks requires a policy framework in which decisions are prepared and co-ordinated on the basis of scientific and other considerations, and international texts provide the foundation for dispute resolution.

11.1. Design or expand co-operation mechanisms on a case-by-case basis

Analysis shows that while practices of risk management may vary substantially from one OECD member country to the other, the fundamental principles and aims of risk management have much in common. As shown by the Codex Alimentarius Commission in the sensitive area of food safety, methods and institutional mechanisms can be created that are conducive to multilateral dialogue and to international risk policies based on consensus. Such mechanisms need to be designed or expanded on a case-by-case basis, depending on the specific risk context they address. In general, the objective should not be to impose uniformity in risk management principles and practices, but rather to seek consistency and coherence among the variety of approaches.

11.2. Aim at an internationally consistent assessment of risks

In the first place, co-operative structures need to rely on an internationally consistent assessment of risks. On controversial issues, what is required is advice from an international scientific committee, either existing or to be created, founded on irrefutable expertise and genuinely independent. The International Panel on Climate Change and the International Commission on Radiation Protection can be seen as models for such advisory bodies, in terms of both composition and role. On the basis of such consensual assessments, far-reaching co-operation can be envisaged and binding agreements elaborated when the risk of free-riding makes that necessary.

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However, irrefutable scientific information and advice might be difficult to collect for a considerable number of risk issues. In such cases, examples from the past show that effective co-operation can be undertaken on a consensus basis by a small number of countries, and then gradually extended, notably through peer pressure. The Vienna and Paris Conventions defining the international nuclear liability regime, for instance, followed such a process.

11.3. Create partnerships to alleviate the costs of risk reduction

Still, risk reduction co-operation might remain difficult to launch in cases where the costs of action are immediate and the costs of inaction only materialise in the long term. International co-operative structures therefore need not only to promote dialogue but also, through that dialogue, to identify and facilitate solutions. One strategy would be to identify specific cost elements which can be alleviated thanks to dedicated partnerships, *e.g.* aiming at enhancing technological innovations (see also Section 5). Synergy between international negotiations and increased research efforts has proved highly effective in the case of the Montreal Convention regulating the use of CFCs.

Specific recommendation for further OECD work

The increasingly international dimension of major disasters places particular demands on the emergency/civil protection services of individual countries as they face up to the special challenges of cross-border spillover effects from disasters. They need to co-ordinate emergency response measures across frontiers and to learn from emergency management in other parts of the world. It would seem that, apart from some very effective regional networks (*e.g.* in the Nordic area, or the Asian Disaster Reduction Center), few international fora exist for exchanging experience and fostering communication and planning among representatives of those services worldwide. It is recommended that the OECD explore the possibilities for creating such a forum, one that would bring together emergency management specialists from across the member country area and from key developing countries.

5. Making better use of technological potential and enhancing research efforts

As this report has emphasised, while technologies may often be the factor underlying major disasters, they are also without question a key source of disaster management tools and solutions – for monitoring and surveillance, prevention, emergency preparedness and response. The potential for new technologies in these areas (*e.g.* satellite observation and imagery, remote sensing, mobile communications, high-performance computing) is enormous, but realising that potential will require substantial investments, considerable efforts in R&D and training, and determination and innovativeness in establishing appropriate policy frameworks. Three areas for action stand out: the need to create incentives, partnerships and viable business models for the development and implementation of promising new technologies; the need to pay greater attention to technological devices and designs that reduce the vulnerability and increase the resilience of systems; and the need to improve the broader context – regulatory regimes, rights and obligations, public acceptance – so as to facilitate the emergence and diffusion of risk management technologies.

Recommendation 12: Improve support for promising new technologies

The obstacles, real or potential, in the path of new risk management technologies are many and varied. To begin with, there may be an issue of the scale of investment required and concern about low or lengthy return on the investment. Space-based monitoring is a good illustration of these problems. Huge investments are required in the first place to develop and then launch earth observation satellites, and then the appetite of commercial investors is further diminished by the prospect of a lengthy and uncertain cash flow from the venture. Moreover, the use of some technologies that could be highly beneficial to disaster management are restricted to military purposes and may, for institutional or security reasons, not be easily transferable to other uses. A number of other promising new technologies may not come to fruition because of the absence of venture capital, the difficulties of finding a suitable business partner, problems of user-friendliness, or the lack of a sufficiently large market.

12.1. Review the interface between the public-good characteristics and the commercial dimension of key technologies

Governments and the private sector are called upon to make more rapid progress on all these issues. On financing costly space-related risk management technologies, for instance, both should pay attention to what is an increasingly important issue: the changing interface between the public-good characteristics of satellite launchers and space applications, and their commercial dimension. What needs to be explored in particular is whether new business models and new public-private partnerships are required in such endeavours, and what these might look like. Interesting recent models do exist, *e.g.* Inmarsat and Galileo.

12.2. Create public-private partnerships in support of R&D for selected technologies

It is also urgently necessary to step up the search for public-private partnerships supporting the research and development of many technologies that hold considerable potential for application in disaster management.

Greater use of these partnerships can increase responsiveness to needs and enhance the efficiency and cost-effectiveness of innovation policies. The types of innovation partnerships that should be explored include general research support, informed collaborations, contract research, cluster formation and human resource development.

12.3. Intensify the application of "reconverted" technologies to disaster management

This report has pointed to the increase in the number of technologies that have found their way from a variety of uses to risk management applications in recent years. In particular, many defence and intelligence-gathering tools have been effectively reconverted in disaster management (GPS, remote sensing, synthetic aperture radar systems). However, more could be done to identify dual-use technologies in the military arena and to overcome what may prove to be unnecessary institutional and/or security barriers to their application in areas such as search and rescue or seismic damage assessment.

Recommendation 13: Explore and develop tools that reduce the vulnerability and increase the resilience of systems

Whether the system in question is a critical energy or telecommunications infrastructure at risk from terrorist attack, a public health system confronted with the spread of a known or new infectious disease, or an entire industrial sector threatened by technical disruption of vital supplies, the analytical chapters of this report identify two major strands of vulnerability: structural weaknesses in the physical installations crucial to the system (*e.g.* dams, power generation facilities, hospitals) and "architectural" weaknesses in system design (*e.g.* just-in-time systems geared to a single computer hardware supplier, power transmission lines or telecommunication cables with little or no backup capacity). There is ample scope for action on both counts.

13.1. Detect and reduce structural weaknesses in key installations

The development of new technologies such as remote sensing can make a considerable contribution to risk prevention by providing early warning of structural weaknesses in dams, transport infrastructures and other key installations. Application of these technologies, however, is not widespread and would benefit substantially from efforts to accelerate their diffusion.

Similarly, the upgrading of existing structures needs to be targeted through the development and strict implementation of technical norms. Reviewing and enforcing building codes for old structures in earthquake-endangered areas, for instance, can go a long way towards limiting the consequences of major disasters.

13.2. Encourage the integration of system redundancies

Both public and private actors need to pay more attention to two important resilience-enhancing features: redundancy and diversity in technical systems. This report cites several examples of systems whose in-built redundancies offer vital protection against breakdown or catastrophic damage [*e.g.* the Internet, the US Federal Aviation Administration's Air Traffic Control System (ATC)], but also numerous examples of costly disruptions – in particular to critical infrastructures such as telecommunications and energy transmission – whose severity could have been greatly lessened by the presence of redundancies, backup systems, etc. Clearly, governments and regulators have a role in providing the appropriate foundation for integrating such system redundancies, for instance through the introduction of emergency infrastructure policy frameworks where these do not yet exist, or for increasing levels of redundancy to match greater levels of risk (even though the initial cost may be considerably higher). But there is also scope for private sector initiative, as demonstrated by the recent moves by Asian telecommunications companies (Arcstar) to improve disaster recovery, and by the work of the American Network Reliability and Interoperability Council to maintain telephone, cable and Internet networks in case of a major disaster. In addition, there is a strong case for augmenting diversity in the use of hardware and software for critical infrastructure systems – a move that both the public authorities and corporations could encourage individually and collectively through, *e.g.,* public procurement policies that take more account of the potential cost of major system failure.

Specific recommendation for further OECD work

It is recommended that the OECD use the opportunity offered by the planned work on the commercialisation of space applications to explore, together with governments, space agencies, launchers, satellite operators and end-users, 1) the long-term prospects for space-based applications such as earth observation, meteorological monitoring, navigation and tracking, telemedecine, tele-education and so on, and their potential utility to risk management, and 2) the need for new business models and possibly public-private partnerships to develop those applications in the interests of risk management.

Annex 1

OECD Futures Project on Emerging Systemic Risks

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OECD PUBLICATIONS, 2, rue André-Pascal, 75775 PARIS CEDEX 16
PRINTED IN FRANCE
(03 2003 01 1 P) ISBN 92-64-19947-0 – No. 52725 2003